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FLIGHT

AIRCRAFT, SPACECRAFT, MISSILES

Official Organ of the Royal Aero Club First Aeronautical Weekly in the World Founded 1909

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Dear Mr Masefield . . .

NO news more welcome to light-aeroplane pilots could have buzzed over the aeronautical grapevine than that Bristol may be the builders of a new British light aircraft. For ten years we have waited and some of us have meanwhile bought executive twins and singles from overseas because we could wait no longer. So with the keenest possible interest, Mr Masefield, we wonder about the sort of machine your designers will give us. A single? A twin? A pusher? Suitable for training and aerobatics or only for touring? What engines? How many seats?

Most of us have ideas of our own; so we ask you not to think it presumptuous if we suggest the type of light aeroplane that we who will fly it should most like to see.

It is our conviction that a resurgence of "off-airways" flying in Great Britain (and in Europe) can come about only through merchant adventuring by the private and business owner. So our new aeroplane should be twin-engined (with adequate performance on one) and a four-seater, with a cruising speed of 170 miles an hour. If it could be adapted for use in an aerobatic category, so much the better, because most of us who now aspire to fly on business have an occasional longing to brush away the cobwebs by flying just for fun.

A Market is Open

The size of our new aeroplane (in which we have more than an avuncular interest) seems to us critically to affect its chances of sale. The market for the bigger twins must already be close on saturation from the outpourings of those responsible for the excellent Apaches and Aero Commanders, Cessna 310s, Travel Airs, Moravas, and Piaggios. But in this press of competition the smaller twin—with room for four and 120lb of baggage—has been strangely neglected.

No one would deny that the design of a successful light twin—fast, economical in fuel (11gal/hr?) and take-off distance (600ft?) and with a practical range of 4½hr—must be a tricky design exercise; but, then, to make up ten years' leeway with one design is a task well worthy of the mettle of a company which is tackling a project so advanced as the Bristol 188.

This matter of design leeway is of the greatest concern to all of us. Gone must be the days of short-life components, engines that are noisy, and installations that 100hr from new become an oily mess. Never again do we want to see oil trickling down flaps or undercarriage legs, wheel brakes that overheat if we use them on landing, cockpits that let in the wet, and finishes that fade in the sun and the rain.

With the greatest respect for your own wide experience and the skill of your design team we beg you all to fly and to study, and to study again, the features for which we find US and continental aeroplanes so excellent. There is still room for improvement, but improvements must start from the best available. Please take a good look at cowling fasteners, at nosewheel steering, at the fuel tank selectors, the sliding seats and the sun blinds. Examine the cockpit heating and ventilation, the logic of instrument markings and the accessibility of the circuit-breaker panels. Assess how the difficulties and uncertainties for the amateur pilot have been reduced by placarding all the drills. And particularly, observe how the airliner arts of upholstery and interior design have been applied to easy-to-clean little aeroplanes.

Then give us a sleek airframe, better controls, ample provision for navigation aids, responsiveness at high speed, natural stall warning, bigger flaps, better laid-out instruments and even more visibility. Because we believe that if you do you may number your sales not in tens or hundreds but in thousands.

FROM ALL QUARTERS

Government "Injection"

INCREASED Governmental support for promising civil aircraft projects and aero-engines, and a possible contribution towards the initial costs of launching a new type, were among decisions announced by the Minister of Aviation, Duncan Sandys, in a Parliamentary statement last Monday. He said that in suitable cases, to enable earlier delivery dates to be offered, the Government might take a share in the risks involved in producing a limited number of aircraft beyond those for which firm orders had been received. It might be prepared to contribute towards the cost of providing a new type of civil aircraft and introducing it into regular service, with suitable arrangements for the Government to participate in the proceeds from sales. Mr Sandys said he could not give any idea of the amount of money it was intended to inject into the aircraft industry.

Making his statement in reply to questions, the Minister said he appreciated the prompt manner in which the aircraft industry had responded to his suggestions for creating stronger units by the amalgamation of suitable firms. The initial process of re-grouping was now virtually completed, though much remained to be done by the new groups to consolidate their resources.

Mr Sandys commented that the sharp reduction in Government orders for military aircraft, representing such a large part of the industry's business, had made it urgently necessary to expand sales of civil types at home and overseas. The Government had been considering ways of helping manufacturers adjust themselves to this changed situation. A substantial programme of aeronautical research was to be maintained for the present; orders were to be concentrated on the five major groups ("except where specialized requirements of public policy make it necessary to do otherwise"); and the Government would "seek to harmonize" the characteristics of military and civil types of transport aircraft. A fuller account, and commentary, will appear next week.

The New Air Transport Board

BY the time these words appear the Minister of Aviation should have presented to Parliament the Civil Aviation Bill. This will include, amongst other things, the long-awaited proposals for the new Air Transport Board. The proposed new legislation was given a first reading on Monday, February 15, having been discussed with representatives of the corporations and the Independents last week.

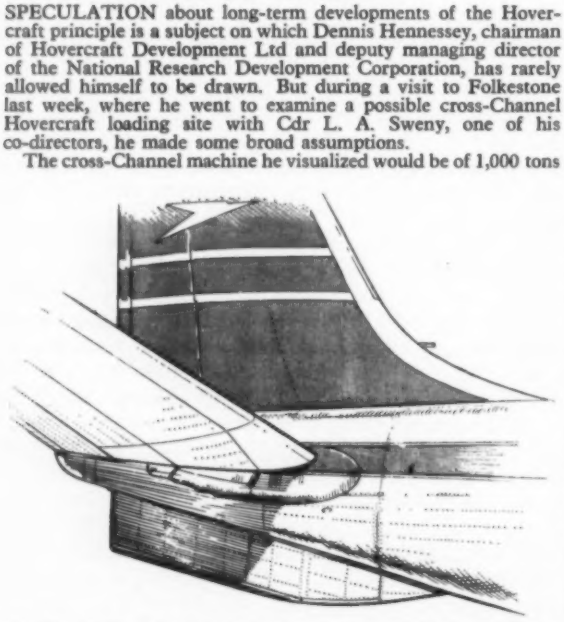
Channel Ports and the Hovercraft

SPECULATION about long-term developments of the Hovercraft principle is a subject on which Dennis Hennessey, chairman of Hovercraft Development Ltd and deputy managing director of the National Research Development Corporation, has rarely allowed himself to be drawn. But during a visit to Folkestone last week, where he went to examine a possible cross-Channel Hovercraft loading site with Cdr L. A. Sweny, one of his co-directors, he made some broad assumptions.

The cross-Channel machine he visualized would be of 1,000 tons laden weight, 320ft long with a 120ft beam and capable of a speed of up to 100kt. It would probably be powered by ten large gas turbines driving fans and would be able to clear 12ft waves.

The site that the party examined was on the foreshore west of British Railways' harbour pier. Mr Hennessey said that the site he had seen would necessarily involve a great deal of civil engineering, and he hazarded that a company operating a Hovercraft ferry across the English Channel would require about £20m capital to cover the cost of two craft and terminal facilities. So far no organization has announced its intention of developing such a Hovercraft or setting up an operating company, although a decision on the construction of smaller precursors to the 1,000-ton vehicle may soon be made.

Studies on ground-effect machines also continue in the United States. The Office of Naval Research has awarded Ryan a contract to analyze the structural criteria of a variety of air-cushion riders. The structures to be studied will range in overall dimensions from 20ft to several hundred feet.



VENTRAL FIN as now fitted experimentally to BOAC's second Boeing 707 is one of the modifications necessary to meet the ARB's handling requirements ("Flight," February 5). Although ARB validation of BOAC's 707-436 is still awaited, the -420 series has just been certificated by the FAA at the following weights; Max taxi, 312,000lb; max take-off, 311,000lb; max landing, 207,000lb

Air Traffic Award

FOR "their foresight in the formation of the UK Air Traffic Control Service," the RAF has been awarded the Hunt Trophy for 1959 by the Guild of Air Traffic Control Officers. Taking the form of a silver salver, it was presented by the Master of the Guild, K. I. Pearson, senior controller at Farnborough airfield, to Air Cdre H. J. Hickey, AOC the Traffic Control Service, at a dinner in the House of Commons last Saturday evening. The trophy, which was presented to the Guild by Capt V. A. M. Hunt, Director of Control and Navigation (Development and Planning) at the MoA, is awarded annually for the most outstanding contribution to air traffic control.

CAS on the Future

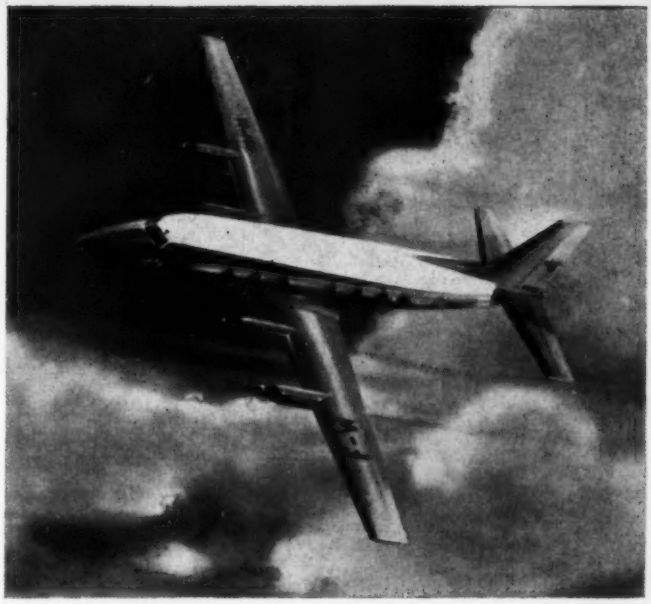
IN one of his first public speeches since becoming Chief of the Air Staff, Air Chief Marshal Sir Thomas Pike spoke at London University Air Squadron annual dinner last Friday about the RAF's assets and its prospects for the 1960s, with "a considerable future for manned aircraft" as his underlying theme. Our V-bombers (not all of them yet in service) were "the finest in the world"; rockets were with us and here to stay, but they did not have the mobility and versatility of bombers. The Lightning would be in service next year; the TSR.2, now in an advanced stage of development, was to be introduced in a few years' time. Sir Thomas spoke of the increasing importance of transport aircraft as the threat of global war receded, and said the RAF considered there was "a long future" for strategic transports. There would be five times as many helicopters, with ten times the carrying capacity. The aim was to take the Army to a strategic centre, and put them into wherever they wanted to go. Both STOL and VTOL types of aircraft had "a tremendously important military future."

Boscombe's Farewell to "The Boss"

SOMEBODY had the happy idea, seven years ago, that representatives of aircraft firms at Boscombe Down should get together socially with the RAF and Ministry staff there. This year's meeting, at the congenial White Hart Hotel in Salisbury on Wednesday last week, had all the ingredients proper to such occasions: an attendance of 103 (the biggest ever); a buffet supper, so that no one was debarred physically from perambulating for a non-stop gossip with old friends (or enemies, but with swords sheathed for the evening); good aeronautical talk ranging from the RFC and airships and flying boats to Blue Steel and variable geometry and VTOL; and the special accent, though in a slightly saddened key, of a presentation to Air Cdre A. E. Clouston on the last occasion he will attend such a function as Air Officer Commanding the A & AEE.

This part of the proceedings was admirably introduced by R. E. Pearce of Bristol Siddeley, who stressed the value of such gatherings, when aircraft firm representatives met people who in the course of business were "names at the end of telephones or on pieces of paper." He went on to speak of Air Cdre Clouston's departure from the Establishment at the end of March, though not (he thought) on account of old age. On previous occasions the AOC had "taken the mickey out of us"; now it was their turn to take the mickey out of him. Perhaps he was going into the brewery business, or even into aviation? But there was no doubt (despite the banter) of the esteem and affection in which "the boss" is held, and it was marked tangibly by the presentation to him of a model of the D.H. Comet—not the post-war turbojet but the pre-war propeller type in which he made his record flights —by E. Vousden of Fairey, the senior representative present.

Naturally Air Cdre Clouston had his quip in return: the



POTEZ 840 is the designation of France's forthcoming light transport, first mentioned in "Flight" last week. The turboprops are Turboméca Astazous, each rated at 436 h.p. Passenger capacity will be 16 to 24

model's shape was wrong: aerodynamically it was wrong: "I know every inch of that machine." But with typical sincerity he went on to pay tribute to his hosts—"how much we appreciate the representatives and their thoroughness." Thirty-six firms, he said, were represented at Boscombe; and there was the "finest of close liaison" between them and the Ministry and RAF. He paid tribute to the companies' "understanding and good co-operation." Finally he had a personal word, that after 30 years' service—which he had thoroughly enjoyed—he was happy that the RAF had let him join; and at 52 was looking forward to starting on a new life and fresh adventures.

Gliding Congress Details

DATES have been announced for the 7th congress of the gliding research organization OSTIV, to be held at Cologne during the World Gliding Championships. The official opening will be on Tuesday, June 7, and the meeting will close on Friday, June 17. Delegates are expected to be accommodated at Butzweilerhof Airfield, where the championships are taking place.

Papers will be presented at the meeting on technical and meteorological subjects concerned with gliding, and there will be discussions on the draft airworthiness requirements for standard-class sailplanes which are now being prepared by an OSTIV working party. The OSTIV Trophy—first awarded last year to Rudolf Kaiser for his Ka-6—will again be awarded to the designer of the standard-class machine judged (by a special committee) to be the best combination of cheapness, simplicity and efficiency.

Prospective authors of papers for the congress should send details to Alan Yates, City of Bath Technical College, Lower Borough Walls, Bath, Somerset, before April 1.

"Brab" Dines at Fair Oaks

HALF-HEEDED, the seasons slip by, marking but not proclaiming the passage of years. Few men are left who remember flying as it was in the beginning. "None of you can realize," said the guest of honour at Fair Oaks Aero Club's fourth annual dinner on February 5, "the extraordinary atmosphere of those early days; the appalling proposition of getting an engine to start; the difficulty of finding in England a magneto or a turnbuckle, or that unforgettable first moment of leaving the ground."

The speaker, of course, was Lord Brabazon of Tara, himself one of the last of the pioneers. "A sort of human pterodactyl" he sighed, rather obviously feeling nothing of the sort, "and the man who has frequently been described as 'the first certified pilot'."

And apart from a fleeting reference to the present—"I'm the man who barred the certification of the 707"—in deliberate and detailed reminiscence Lord Brabazon then discussed the earliest days of flying, so that fifty years on some of his listeners might say they had heard about it from someone who was there. What was the first public reaction to the first flight by Britain's pilot No 1 (at Issy-les-Moulineaux)? "A taxi driver kissed me on both cheeks." What was Lord Brabazon's own reaction to becoming airborne? "Consternation."

And much more in a similar vein, about the *Daily Mail* prize, the Michelin Cup, flying and not-flying at Brooklands, and early efforts to become airborne. But of all that would never come back, said Brab, what he regretted perhaps most was ballooning—"A real gentleman's way of getting into the air. You didn't know where you were going, how far, or where you would come down. And you didn't care."

Difficult as Lord Brabazon is for any speaker to follow, within three minutes of starting a highly apocryphal account of a wartime flight he had made with Wg Cdr Arthur (the club's chief flying instructor) H. E. Baker (CFI of London Transport Flying Club) had reduced his audience to that near-hysterical state where anything that is said brings renewed laughter. But he brought sufficient sanity to the proceedings towards the end to pay a warm tribute to his old colleague and to read a telegram from the Guild of Air Pilots and Air Navigators announcing that Wg Cdr Arthur had just been awarded the Guild's Award of Merit.

KANPUR 1 is the name of this light aircraft, designed and built in 132 days by Indian Air Force technicians, under AVM Harjinder Singh, at the IAF station at Kanpur. Built entirely of indigenous raw materials, the new four-seater prototype was on display at the World Agricultural Fair in New Delhi

IN BRIEF

Rolls-Royce have signed a contract for the supply of Dart turboprops for the prototypes of the Japanese YS-11 airliner. Worth £297,000, the order is the first to be placed for the RDa.10, of 2,660 e.h.p.

Maurice Brennan, who at the beginning of the year took up the position of chief engineer with Folland Aircraft—now one of the companies of Hawker Siddeley Aviation—has been appointed to the Folland board.

An agreement between the British and Maldivian Governments, granting Britain the use of Gan Island as an RAF base for 30 years in return for financial aid, was signed by C. J. M. Alport, Minister of State for Commonwealth Relations, last weekend.

One of the US Navy's new Goodyear ZPG-3W airships was wrecked last weekend when a gust drove her against a hangar as she was being towed by a tractor at South Weymouth, Mass. Designed for radar early-warning duties, and of 1¼m cu ft helium capacity, the ZPG-3Ws are believed to be the biggest non-rigids ever built.

We regret to record that Air Cdre R. J. Legg, representative in South Africa for Rolls-Royce Ltd, died after a road accident near Pretoria on February 6. Aged 56, he held several air attaché appointments after the war, and went to South Africa in 1952 as senior air liaison officer to the British High Commissioner. He retired from the RAF in 1952.

Our associate journal *The Motor Cycle* recently sent a writer and artist to NSU Werke to bring back a full story—exclusive in Britain—on the revolutionary Wankel engine. A history and description, with cutaway drawing, appeared yesterday, and next Thursday's issue concludes the story.

A reunion dinner for members of the RFC, RNAS and the RAF during the First World War is to be held next Thursday (February 25) at the Royal Empire Society, Whiteladies Road, Clifton, Bristol. Ex-servicemen wishing to attend should contact R. W. Watson, RAFA Headquarters, Carlton Lodge, Eastfield, Westbury-on-Trym, Glos.

Preparations are now under way for the mountain soaring group led by Dr Brennig James to travel to the Himalayas in April to investigate mountain air currents by sailplane flights over the Annapurna range. Dr James had requested permission to attempt to soar over Everest, but the Nepalese government permission was restricted to Annapurna. The expedition will be based on Katmandu and Pokhara, and the aircraft will probably comprise two Skylark 3s and two T.42 Eagles.

Asked on February 9 about his plans for introducing regulations "to enforce all persons operating from private flying clubs to insure against third-party risks," the Minister of Aviation stated in a written reply that (under the Civil Aviation Act 1949) all aircraft owners were legally liable to pay compensation for material loss or damage caused by aircraft to persons and property on the surface. "It is my understanding," the reply continued, "that persons operating from private flying clubs in fact insure against such risks, but the position is now being studied."

IRBM demonstration at Feltwell: (left) a Thor being raised on its launcher to the firing position; (above) Flt Lt Ken Hunter (launch controller) and M/Sig W. Willis (console operator) in the launch control trailer during a practice countdown sequence; (right and far right) two views in the RIM (Receipt, Inspection and Maintenance) building —Ch Tech Norman Clamp checks one of the Rocketdyne MB-3 engines, and Ch Tech John Yeldon watches the rocket control test panel

Missiles and Spaceflight

VISIT TO FELTWELL

Since its inception in February 1957, the Anglo-American programme for the establishment of Thor IRBMs in the United Kingdom has in general proceeded on schedule and is fast approaching completion. We first visited RAF Feltwell, Norfolk, late in 1958, and some photographs of the first Thor pad to be completed there appeared in the description of the whole of USAF Weapon System 315A published in our issue of December 5, 1958. Further information on this IRBM, together with a detailed cutaway drawing, was published in our issue of May 22, 1959, following a visit to the prime contractor, Douglas Aircraft. Last week the Air Ministry invited the Press to Feltwell to see an operational station in being.

Apart from one or two highly classified facts, little about the programme is being withheld. Altogether there are to be four complexes, each consisting of one base headquarters and four satellites. None of the latter are less than 12 miles apart and some are as much as 30, and everything is located on former RAF airfields. Each of the five locations occupied by a complex is termed a squadron, and consists of three emplacements each with a single Thor on its launcher. There are thus to be 20 squadrons each with three rounds, and they are spread around eastern England from Norfolk to the Humber.

Administratively the missile squadrons come under Nos. 1 and 3 Groups of Bomber Command. Excluding the fourth complex, which is not yet complete, the total complement of these squadrons amounts to 319 officers, 1,576 NCOs and 1,177 airmen. Each squadron has five launch crews, living at the base HQ for the complex and driving out to the squadron for their shift on duty; only one launch crew is needed to fire the three missiles (simultaneously, if necessary). Total personnel required to be on duty comprise a launch control officer, three missile maintenance technicians, a power-production operator, a console operator, an RAF policeman, two dog handlers (plus dogs), a cook, driver and fireman. Within the launch-control trailer is also located an authentication officer of the US Air Force (SAC 7th Air Division) who maintains his country's joint control over firings.

Most of the cost involved in putting in the Thors has been borne by the United States. The complexes based at Feltwell, for example, have 15 rounds which, with ground-support equipment and spares, cost £17m. The civil engineering work (largely done by Sir Robert McAlpine and paid for by the UK) amounted to £1.75m, while the training of launch crews cost some £3m. The first squadron's launchers were checked out at Feltwell last March, and this particular complex was operational by June. The second complex was finished last September, the third in December and the fourth and final installation should be finished in June next.

TITAN FLIES AGAIN

Martin's great ICBM entered its flight-test programme with a flourish, achieving four successes with the first four shots. The fourth round (A-6) was launched on May 4 last; and since then Martin's luck has been conspicuously absent. Reports on various malfunctions were given on this page on December 25 and January 8; but it is now possible to record a success.

As we noted on January 8, B-7A, the last of the B series, and the only one to fly successfully, was on pad 19 at Cape Canaveral at the beginning of the year. B-7A was the first Titan to incorporate a powered second stage, earlier Titans having a dummy second stage ballasted with water. That of B-7A was just over 40ft in length, weighed 48,000lb when filled with liquid oxygen and RP-1 and was powered by an Aerojet-General LR91, rated at 67,000lb at sea level and 80,000lb above the atmosphere. Within it was carried the airborne part of the BTL/Remington Rand radio-inertial guidance system, which for the first time was coupled to the engines of both stages. As noted in our special "Missiles" issue last November 6, this system has supplanted the original inertial system (transferred to Atlas), pending development of Titan's definitive AC Sparkplug/IBM light-weight inertial system. It is also worth commenting on the choice of a remarkably blunt nosecone. This cone was first worn by the first B-Titan, which exploded on the pad last August 14. The operational nosecone should be the pointed ablative model currently being developed by Avco. At present the C-series missiles appear to be wearing the old heat-sink pattern, covered by an aerodynamic fairing to improve performance on the climb (picture, December 25, p. 773).

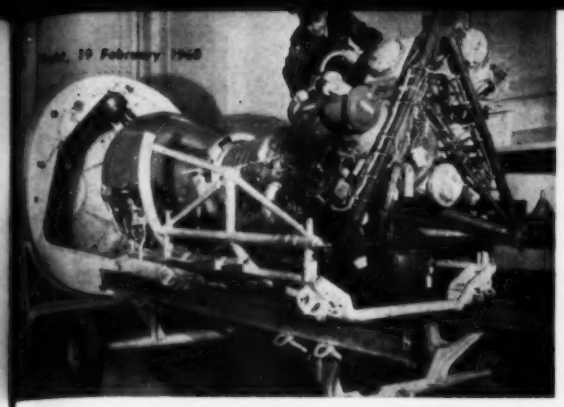
After aborting on January 27, as a result of a turbopump overspeed, B-7A left at 1.8 p.m. local time on February 2. Stage separation came after 124sec and the LR91 lit up successfully. This is much the largest engine outside the Soviet Union to have been ignited *in vacuo*. Total distance covered was some 2,200 miles, and nearly all test objectives were achieved.

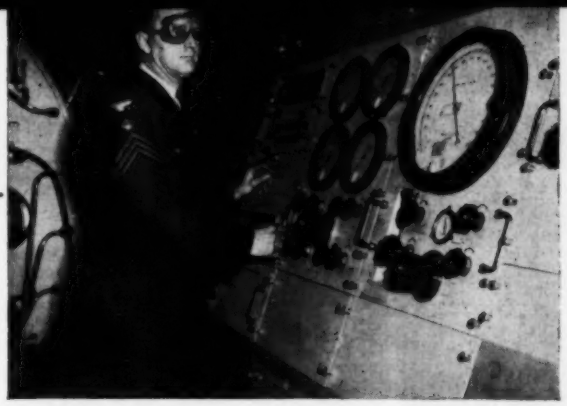
Now that the Bs have been expended, future flying will concentrate upon the C-series, which are capable of evaluating most of the airborne functions of the operational weapon. Pad 16 at Cape Canaveral is at present fast approaching a serviceable state, following the explosion of C-3 on December 12. Several additional C-Titans are due to be fired within the next few weeks.

PREACHING TO THE CONVERTED

Before the British Interplanetary Society at Church House, Westminster, on February 10, Prof Alla Masevich of Moscow University presented an appropriately revised version of the review of the Soviet space programme which she had given at the Royal Festival Hall the previous Saturday. The lecture, which was illustrated with slides, included a detailed account of the organization, equipment and problems involved in tracking the Russian satellites and space probes.

Among the problems mentioned were several attributable to human error—it had taken astronomers several months, for





example, to learn to use stopwatches accurately when observing Sputnik 1; and it had in fact been found that untrained people did a better job. While Russia was most grateful for the many thousands of observations which had been received from all over the world, those concerning the impact of Lunik 2 were rather confusing. Reports from the Soviet Union, Britain, Sweden, Hungary and Poland had been received on this; some observers had seen a bright spot, some had seen a dark spot, and others had seen spots in an area situated a long way from the impact point. "Probably these observations were not very real," commented Mrs Masevich.

The planned Soviet "moonwatch" organization had been based on 70 observing teams, at stations separated by distances of at least 1,000km, but the response from volunteers had been so great that more stations than were really needed had been set up. Each team had about 30 moonwatch telescopes ("not more than three or four" are now used per team because of the brighter current satellites); larger telescopes able to trace stars of the eighth magnitude were also employed; and 26 photographic stations used modified aircraft cameras giving a 50°×30° field of view.

Since the launch of Sputnik 1 on October 4, 1957 a total of some 70,000 visual observations had been made, including 30,000 from a total of 35 foreign countries.

Professor Masevich

Before the first Soviet lunar probe was launched, Prof Masevich said, a sounding-rocket experiment had included the release of a cloud of sodium vapour at a height of 430km (27 miles). From this the air density at this altitude had been obtained. The results from many methods involving satellites and probes had shown that the high-altitude densities were 5-10 times greater than indicated in previous theoretical models. The sodium cloud released during the flight of Lunik 2 was not intended to provide scientific information, but served as a tracking aid in case of failure of the radio transmitters.

After describing the equipment carried by Lunik 3, Mrs Masevich said that a second transmission of all the Moon photographs had been planned for February 7, when the probe reached its perigee position of approximately 9,000km from the Earth. This would have provided a much clearer set of images than those actually transmitted from 400,000km, but was prevented by the prior cessation of Lunik 3's radio transmissions, which was assumed to have been caused by meteor impact. The films transmitted were still being analysed, and it was hoped soon to publish an atlas of the Moon.

MINITRACK IN ENGLAND

A Minitrack station for the tracking of Earth satellites and space probes is to be set up in England by the US National Aeronautics and Space Administration. This news was given in Washington on February 16 by Arnold W. Frutkin, Director of the NASA Office of International Programs, who said that another Minitrack station was planned for Newfoundland. These new units were designed to extend latitudinally the US tracking network.

The proposed UK station will be located on a site at Winkfield, near Windsor, already used as a tracking station by the Radio Research Station, Ditton Park, Slough. The official agreement is being concluded by NASA and the UK Department of Scientific and Industrial Research, and with the approval of the Government's Steering Group on Space Research.

Agreement in principle has already been reached, and preparations have begun for the installation of the US equipment at Winkfield. Assuming completion of the negotiations, it is hoped to have the station in operation by the end of the summer.

BLUE WATER—OFFICIAL

In the House of Commons on February 11, the Defence Minister, Harold Watkinson, said: "Our own weapon called Blue Water is a surface-to-surface missile which is intended to replace the Corporal as the weapon for support of armies in the field. It is a short-range weapon of 30 to 40-odd miles at the moment. The countries of Western European Union have agreed that there is a need for such a weapon and that its military characteristics are considered right for the purpose." The missile had not previously been officially referred to by name, nor had its range been divulged.

The US Defense Department announced on February 10 that American tracking stations had detected an unidentified object in a near-Polar satellite orbit. The announcement said that the object "might be of Russian origin."

The Royal Australian Air Force base at Butterworth, Malaya, will soon receive its first Sidewinder air-to-air missiles (for use on Sabres), according to AVM Sir Frederick Scherger, RAAF Chief of Air Staff.

On February 5, No 57 Heavy Anti-Aircraft Regiment, Royal Artillery, was disbanded at a ceremonial parade at the Royal Artillery barracks at Woolwich, London. This regiment was the last to be equipped with the 3.7in AA gun; all future "heavy" anti-aircraft units will be equipped with Thunderbird.

Scientists at Stanford University have established radar contact with the Sun by reflecting short-wave pulses from the hot gas of the solar corona, about 500,000 miles from the Sun's surface. Disclosed on February 4, this contact was made last April.

The 35th successful drop of test capsules for Project Mercury was made on January 30 from an aircraft flying at 31,000ft. Two parachutes were used for the descent, which was made into the Salton Sea, about 120 miles south-east of Los Angeles. The company responsible for these tests is the Northrop Corporation.

Radio messages and a photograph were transmitted from Washington to Hawaii via the Moon on January 28 by the US Navy. The Service said that this technique had already been used "in a limited operational way" when atmospheric disturbances had affected ordinary straight-line communications.

Following the unsuccessful attempt to place Discoverer 9 in orbit (*Flight*, February 12), the USAF announced: "Discoverer 9 failed to achieve orbital velocity and fell back into the Earth's atmosphere after a successful launch. Radar data is being analysed to determine the cause of the insufficient velocity of the vehicle." It was not known whether the second stage had successfully separated.

Sputnik 3 completed its 9,000th orbit around the Earth on February 1. In the 626 days since it was launched it had covered some 253,368,000 miles, and its period of rotation had decreased by 13.1min to 95.85min. Apogee had declined from 1,168 miles to 398 miles. According to predictions by the Radio Research Station, Slough, confirmed by Prof Alla Masevich, Sputnik 3 should re-enter the Earth's atmosphere about mid-March.

Gen Curtis LeMay, Vice Chief of Staff of the US Air Force, said recently that the Douglas Skybolt ALBM would be launched by the Convair B-58 Hustler. This does not, of course, preclude its use by the B-52 and possibly even by relatively small aircraft, but it is the first time that the ALBM has been definitely associated with an aircraft type since the virtual cancellation of the B-70 Valkyrie. The first wing of 36 B-58s should be operational from Carswell AFB by the summer.

Academician Semyon Volfkovich recently told the Tass new agency, "The fuel and oxidizers proposed by Soviet scientists can, apparently, be regarded as the best of all propellants mankind now has at its disposal for space flights." He also commented on the record re-entry speed of the recent Soviet rocket which impacted in the Pacific, and said that Soviet chemists had evolved "special alloys and other materials" for the nosecone.

The Martin Company are installing Missile Master electronic air-defence co-ordinating systems in Boston, New York, Los Angeles, Chicago, Pittsburgh, Detroit, Buffalo and Philadelphia: two sites are already operational covering Washington/Baltimore and Seattle. The company were recently awarded a $3.3m Army contract to provide publications and training for Missile Master maintenance personnel.

Maj-Gen John B. Medaris, who retired on January 31 as head of the US Army Ballistic Missile Agency, writes—in our contemporary *Missiles and Rockets*—that the separation of American space programmes into civil and military portions is "fundamentally unrealistic." He advocates the creation of a single missile/space agency under a joint military command. He described the contention (expressed by the President himself) that the armed forces have no business exploring space as "utter nonsense."

What Course for the Independents?

FRANK BESWICK Interviews Four Private-enterprise Airline Chiefs

IN this article—the fourth of the series eliciting the views of leaders of industry on topics of outstanding importance—Frank Beswick turns from aircraft manufacture to air transport. He presents the views of four prominent independent operators, obtained on the eve of this week's legislation which is expected to place the private-enterprise airlines on a new footing vis-à-vis the corporations. Mr Beswick, formerly MP for Uxbridge, has for many years been closely identified with aviation politics.

IN any consideration of the future of the independent air transport companies it is natural that one should seek the opinions of **M. D. N. Wyatt,** the chairman and managing director of Airwork Ltd. He has been associated with this side of the business as long as most. The first question I put to him was: *You have come across plenty of difficulties in the past; would you agree that the outlook for the independent operator looks more hopeful now than at any time?* This was his reply:—

"The situation is more malleable now, and if all we wanted was to become a large outfit then the chances are probably better today than before. But we also want to make a reasonable profit from our operations, and that is a very different matter."

What role do you wish your group to play in the future?

"We want to be allowed to compete on fair terms for a share in new opportunities as they occur. Air transport is still young and no one can tell what the pattern will be ten or twenty years hence. We seek a situation where we shall be allowed to exercise our ingenuity and energy in helping to develop the industry—and in the process to help ourselves.

Can you particularize?

"It is impossible to know how things will develop. Some scheduled operations as a bread-and-butter basis are necessary; the modest services down to Africa might be thickened a little; and then there is the Air Bridge. I would not have thought there was a great future for all-freight services."

M. D. N. Wyatt

What do you want the Government to do for you?

"If they will remove the throttling monopoly which the two corporations enjoy and will establish a licensing authority somewhat similar to the CAB—but, for heaven's sake, not so slow-moving—they will have gone some longish way to satisfy our requirements.

"To be effective, the licensing authority must insist at all times on first-rate operating standards and before granting any licence it should certainly require from the applicant satisfactory evidence of sufficient financial strength to carry out whatever project may be the subject of the licence. The independent companies, in common with the corporations, should then be free to apply for licences for all kinds of air transport and on all routes. The licensing authority would be fully competent to protect the interests of sitting tenants. At the moment we are precluded from doing almost anything, whilst we want to be able to apply for almost everything—provided, of course, we can justify the position. We want the right in law to put in our applications. But let no one think we have any grand schemes for taking over all work in any continent."

What are your plans for new equipment?

"We recently bought a sizeable fleet of Viscounts and Britannias. Our prime task is to keep them at work long enough for them to earn sufficient depreciation to enable us to write them off in our books. When that time draws much nearer we shall begin to think seriously of re-equipping."

What do you think about "rationalizing"?

"It's a wonderful idea. We probably have more experience of it than most people. But before you can rationalize, the terms have to be rational. In some cases this presents difficulties."

So far, what does your experience show? Are there great advantages?

"There *are* advantages, though they can be exaggerated. And merging alone does not help anybody. Moreover, I would not like to be at the head of a concern that became so big as to be what might be called spongy."

* * * *

Then there are the smaller companies. For views on their role I turned to **Gp Capt C. A. B. Wilcock**—not in his capacity as a Member of Parliament but as chairman of Derby Aviation. This is an organization which has just celebrated its 21st birthday and is now extremely active and successful, but with no very heavy aircraft and no long-haul scheduled operations. I first asked,

How do you see your role in the future?

"We can look after the local services—parochial, if you like. At Derby we have local men and women serving local firms and people, and doing it very well. There is a local pride about it, and we aim to build similar connections and a similar spirit in other selected areas. For example, we are developing a route from Luton through Derby to Dublin. No large corporation could give the areas around Derby or Luton the services which we are prepared to offer."

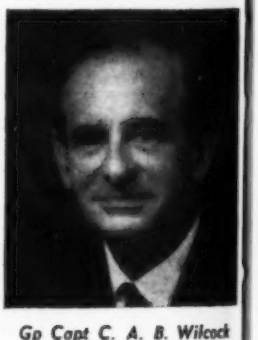
You visualize yourselves as a feeder line, filling in the gaps of the main network?

"Not entirely; we offer a variety of services. Of four aircraft which have just taken off, one is carrying a Rolls-Royce engine to the South of France, another a helicopter to Africa and the third a small party to winter sports; the other is on its scheduled service to Glasgow. That is a representative batch for this time of year; it is useful work to my firm and, I should have thought, to the community. Moreover it does not need your big new 180-seater jets to carry out."

And what do you require from the Government if you are going to maintain progress in this field?

"There is the question of fares—the so-called fare-structure—which, of course, affects a lot of other people besides ourselves. If we can offer a cheaper ride on an older, slower, but equally safe machine, then why should not the passengers be free to travel with us if they choose? Bear in mind, too, that there will always be older aircraft; the new type of today is the old machine of tomorrow, or at least the day after.

"Then there is the question of security. If we are going to spend time and money on the development of new routes we do want some guarantee that at a later date they won't be handed over to some other 'chosen instrument'."



Gp Capt C. A. B. Wilcock

But presumably the smaller companies will need to re-equip at some time; is this not going to put an intolerable strain on them, with the cheapest aircraft probably costing £150,000 each?

"Not necessarily. But if the Government are serious about helping the aircraft industry and wants to pump new blood into it, then there can be no better way than by helping us to buy new aircraft. If they could cut out the present high loan-charges, by interest-free loans or something like that, then that would help. But let me add that right now one just cannot go out, even with the money available, and buy new British machines ready to do the job we want to do from the airfields we want to use. Those machines simply don't exist."

Would you say that rationalization has any message for you? Is it inevitable or likely that the smaller firms will have to merge?

"Not inevitable, though a certain amount of tidying-up could bring advantages. I am not thinking so much of take-overs or mergers, but among four or five of the smaller operators there could be economies if they got together. I should call it co-operation rather than rationalization. For example, in such matters as pooled maintenance, or joint operation of bigger machines to ensure maximum utilization, or the joint operation of a particular service. Then, again, there would be merit in having one representative organization for these smaller companies through which

(Concluded on page 258)

FLIGHT

SYSTEM SURVEY

This "Flight" special feature contains the first detailed review of automatic landing for civil aircraft yet published and an investigation of progress in inertial navigation (pages 247-252). The general discussion below is followed by reports on BEA and BOAC plans (pages 238 and 241) and reports on ILS (page 244) and on ARB safety considerations (page 246).

AUTOMATIC LANDING

A REVIEW OF PROJECTS AND PROGRESS

Hands-off landing in a BLEU Varsity at Bedford

AUTOMATIC landing will inevitably become a regular feature of airline operations. That much can be deduced from the work now being done in Britain and America. But it is not yet certain what form the equipment will eventually take, at how many airfields aircraft will be able to land automatically or exactly what the visibility minima will actually be for such operations.

Some definitions are necessary to clarify exactly what is meant by automatic landing. There can be said to be three main categories, namely, auto-flare, automatic touchdown and what might be called automatic arrival. The first implies the automatic control of pitch attitude to produce a flare-out from the approach path to touchdown, the pilot remaining to control the lateral and directional axes to align the aircraft with the runway centre-line and to kick off drift. Although automatic control of throttles, and therefore of speed, is not necessarily an integral part of auto-flare, it will almost certainly be included in any such system. Automatic touchdown implies the automatic control or direction of the complete flare and touchdown in all three axes, with speed control and drift correction. Automatic arrival extends this phase to include the landing run and subsequent movement to the parking area.

The last case logically implies operation in visibility as low as 10ft, with the runway surface virtually out of sight from the cockpit. It therefore also implies that all the supporting ground services such as rescue equipment, refuellers and passenger handling vehicles will be able to operate in the same visibility —a prospect which is fairly remote at the moment and certainly would be extremely expensive to achieve. It is probably fair to say that very little serious and practical consideration is being given to such extreme operations at present, although as an ultimate goal for some decades hence it cannot be ignored.

The term automatic landing in the context of this review is therefore used to indicate automation of the approach and touchdown, with the corollary that, in the visibility minima specified for this automatic landing the aircraft must be able to clear the runway after landing if it is not to block the airfield for other traffic. Minima might be about 50yd, a condition in which ground vehicles could be effectively controlled at a useful speed if some additional sign-posting or guidance were available.

At this point it should also be made clear that the requirement for automation is by no means limited to operations in poor visibility. The equipment can contribute considerably to the safety of airline operations: it can make the landing a more precise manœuvre especially in terms of field-length and might well increase significantly the handling capacity of a given airport.

From the technological point of view, automatic landing represents a new departure in automation, for never before has so critical an operation been committed so irrevocably to automatic control. At present, automatic machines are designed to perform a given operation and to switch off or disengage if a fault occurs. No more than this is really necessary. In automatic landing, any one fault must not even interrupt the operation significantly if commercial passengers are to be committed, and stand-by upon stand-by must therefore be built in to any system. It is in fact these stringent safety considerations which have largely shaped the systems themselves.

It is satisfying to note that Britain, in applying automatic landing, has established a significant lead, attributable first to twelve years of quiet effort by the Blind Landing Experimental Unit and the companies supporting it; second to the imaginative lead given more recently by BEA and BOAC. The RAF has already adopted the military Autoland system developed by BLEU with the assistance of Smiths, Pye, Standard Telephones and Cables and Murphy Radio. The next airliners for BEA and BOAC, respectively the Airco D.H.121 and the Vickers VC10, are to be equipped initially for auto-flare and later for automatic landing and these requirements have been taken into account from the early design stage. No other airline has yet made this stipulation.

In America, the Federal Aviation Agency is well launched on a programme to develop a military and civil automatic landing

FLIGHT SYSTEM SURVEY...

system. Although Britain is first to apply the technique to both military and airline operation, the concerted American programme, backed by considerable financial resources and good publicity, may threaten the British lead in a relatively short space of time.

Clearly ICAO will have to examine the various approaches in order to establish some form of international standard. Here there is real danger that an American system might be adopted regardless of its merit relative to any British counterpart. History has proved this all too clearly. The only hope of achieving an equitable solution lies either in the fortuitous case of the two systems being sufficiently similar to be covered by a single standard (this is not as unlikely as it might seem) or in co-ordinating the two countries' efforts by means of early technical co-operation of the kind begun last year between the MoA and the FAA. Another head-on collision such as that at Montreal last year cannot provide any satisfactory solution. Certain it is that ICAO will have to begin considering the matter within the next five years and British companies clearly must recognize the implications of this fact.

A British ground installation is unlikely to be supported effectively by either of the airline corporations because BOAC is deliberately not committing itself yet to any system requiring special (and therefore standardized) ground equipment and BEA has a special localized requirement which could initially be satisfied by a single ground installation at London Airport alone.

As far as a time-scale is concerned, it would be precarious to make any firm prediction of when automatic landing will become a routine operation, even at one or two airports. The clearest statement is that by de Havilland (*Flight* for January 22) to the effect that they hope that automatic landing in the D.H.121 in BEA service might become routine during 1970—ten years hence. In the meantime it should not be forgotten that Bomber Command aircraft are being equipped for Autoland now—a world "first" which has so far received less recognition than is due.

In parenthesis, it may be added that *blind* landings were successfully made many years ago and that several thousand successful automatic landings—many of them also blind—have been completed on both sides of the Atlantic using a wide variety of systems. The commercial situation is still that, although literally millions of blind or automatic approaches are made in scheduled service each year, not a single normal blind landing has yet been made in scheduled service.

The subsequent sections of this review give details of British and American systems, a summary of the general requirements, a study of the D.H.121 and VC10 projects and a study of ILS which undoubtedly will be the first guidance element for auto-flare.

THE PROBLEM

INSTRUMENT approaches using the purely angular information derived from ILS have hitherto raised no very great problems so long as site-induced ILS errors have not been excessive. The aircraft is flown down the beams to a decision point where the pilot can either see the approach lights to take over and land visually or fails to see them and overshoots. This point can be defined with acceptable accuracy either by the emergence of the aircraft below a cloud-base of known height or, in the overshoot case, by barometric altitude indications which can be rendered sufficiently accurate by appropriate altimeter setting. Only at the transition point is it imperative that the pilot should know his exact position along the glide-path as opposed to his angular deviation from it. Marker beacons and the intersection of the level approach with the glide-path provide convenient approximate references.

The drawing, below left, illustrates the configuration of an approach in the glide-path dimension from 1,500ft downwards. This height will be some 30,000ft from glide-path origin. Distances from origin are given at 300ft, 150ft and 50ft heights because at these points the present automatic landing system switches respectively to Leader Cable, attitude-hold and flare-out. Distances along the bottom of the drawing show how far these glide-path heights are from origin and the times at the top show how long, in seconds, an aircraft will take to fly through these sectors at 120kt and, in brackets, at 100kt. The first speed allows for a slight headwind or still air, according to the aircraft, and the second for a headwind component which is perhaps as high as will apply in really low visibility. The D.H.121, for example, is to have a steady approach speed of 127kt.

The ICAO ILS specification allows an angular tolerance of 0.2° in glide-path (0.6° for the localizer) and the vertical spread in feet at various ranges is shown in the drawing. It is assumed with present ILS that glide-path guidance will have to be released at about 150ft and replaced by open-loop autopilot guidance in pitch down to 50ft where auto-flare takes over. This phase will last for between 10 and 12sec and aircraft must not be significantly displaced from the glide-slope if an undesirable spread in touchdown points is to be avoided. The flare-out, which begins at about 50ft (the actual height depends on the aircraft and its systems), relies on radio altimeter measurements for which smooth ground is required. It is therefore presumed that the aircraft will be established over the runway by the time it reaches this height, but that it will still be some 1,000ft from glide-path origin. The exponential flare-out curve is followed to a touchdown point some distance beyond glide-path origin, this distance being established to some extent by the touchdown rate of descent selected in the flare computer and by the programme set in the automatic throttle control.

As the ICAO standard approach aid, ILS is an obvious basis for extending automation down to touchdown. Yet it can be argued that ILS is not the right form of guidance for landing. Its frequencies, for one thing, are unhappily chosen: if they were lower, site errors caused by reflections from ground objects could be avoided; and if they were higher, the signals could effectively be beamed away from the ground. As it is, site errors and random interference significantly degrade accuracy and reliability of information in the majority of existing installations. The system in any case employs one VHF and one UHF frequency, each with its own problems.

It has been shown that accuracy can be very considerably improved by new aerial systems and that monitors and correctors can be applied without departing from the ICAO specification. But the provision of this accuracy may well entail alterations which would be as expensive as new equipment. Other alterations will be required to provide a degree of stand-by equivalent to that demanded in airborne equipment and to ensure instantaneous changeover to stand-by channels.

It is questionable whether ILS in fact provides the kind of information which is needed for automatic landing. Localizer and glide-path give only angular information. Establishment of position along the approach is assisted in the BLEU Autoland system by the reception of the Leader Cable signals which perform one of the major switching operations at 300ft, some 6,000ft from touchdown. Other key positions are established by radio altimeter signals.

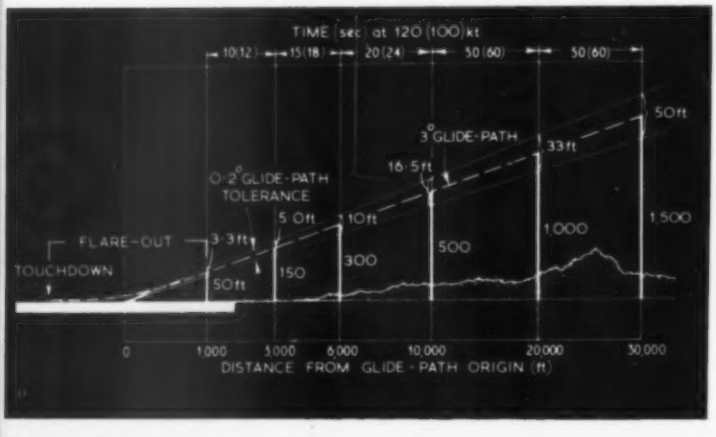
Either a microwave ILS incorporating distance-measuring—something like an aircraft-sampled GCA—or, conversely, some medium-wave, phase-comparison positioning system like Decca appear to be attractive alternatives. Both these lines are being followed and at least four microwave ILS systems are being designed, two in Britain, one in France and one in America. They are still far from completed and there is no guarantee that major difficulties may not arise. Years will certainly pass before any of them can be adopted for civil operations. ILS has been in service for many years and its characteristics, both from the performance and maintenance point of view, are well known. It has been shown that its shortcomings for automatic landing can be overcome with additional equipment.

There seems to be no reason to suppose that ILS will be superseded as a guidance element for automatic landing before 1970. The ICAO standard will more probably be extended for some years, perhaps with rather tighter accuracy requirements.

In early post-war years there was some discussion as to whether ILS or a British Rebecca/Eureka (BABS) system should be developed as a standard civil landing aid. It is not without interest to speculate what the automatic landing situation would now be if the British and not the American system had been adopted.

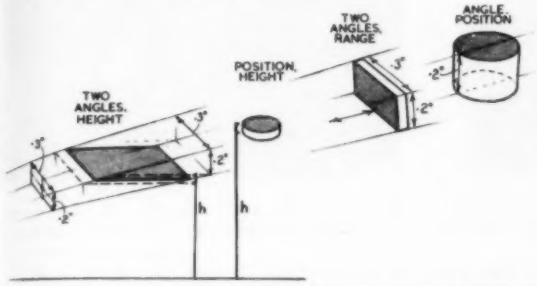
As a long-term prospect, an entirely new system is certain to be developed and it is worth while to consider in which way this

Configuration of an automatic landing, showing distances, heights and times along the glide-path down to the beginning of the flare-out. The distance represented by the glide-path angular tolerance at various ranges is also shown. It is assumed that a radio-altimeter-controlled flare-out must begin over the runway



could be approached. Any system which produces information in a way which can be readily transformed into error signals of the type at present accepted by autopilots will prove adaptable to aircraft presently planned for automatic landing.

During an automatic landing sequence certain critical switching operations will probably have to be performed at the correct point along the approach so that position during the approach will have to be known. The basic parameters from which position may be calculated are vertical angle relative to touchdown, azimuth angle relative to runway centre-line, displacement relative to glide-path and centre-line, and height or range.



An indication of the areas of uncertainty likely to occur when trying to define position along the approach, using various sources of information with and without ILS angular values. Smoothness and continuity of information are also important

ILS provides the two angular values and position may be calculated from these by adding either height or range measurement. The diagram above shows the line of uncertainty which may result if the height term is used because of the considerable horizontal spread allowed by glide-path tolerances for a given height value. The line is extended to a plane of uncertainty by the equivalent angular tolerance in the localizer; and that plane is extended to a volume in proportion to the inaccuracy of height measurement. Nevertheless, accuracy will considerably improve as the vertical and lateral distance represented by the angular tolerances decreases near the beam origins. Vertical spread caused by the lack of a smooth reference surface for radio or sonic altimeter is likely to be excessive until smooth ground occurs shortly before or actually on the runway.

If position co-ordinates were derived from an area-coverage system as accurate as Decca in its optimum coverage—and this accuracy would be substantially constant over the whole approach—position on the glide-path might be derived by adding the height term. Here a cylindrical area of uncertainty would remain whose radius would be determined by positional accuracy and depth by height accuracy. Radio and sonic altimeter limitations still apply. Positional information might be combined with glide-path angular reference, with resultant improvement at points further out along the approach, where height-sensing is poor.

Finally, the two angular values could be combined with range which is after all the most desirable direct measurement. Horizontal spread caused by angular tolerances could be greatly reduced using DME-type equipment and the system would be reasonably accurate at points further away from touchdown.

The criterion is that the system should provide a level of error signal appropriate to the aircraft characteristics, having regard to aircraft inertia and the effect of cross-winds and gusts. At intermediate ranges of about one mile, ILS often requires long time-constants to overcome step errors in the beam and therefore cannot provide the information necessary for tight control.

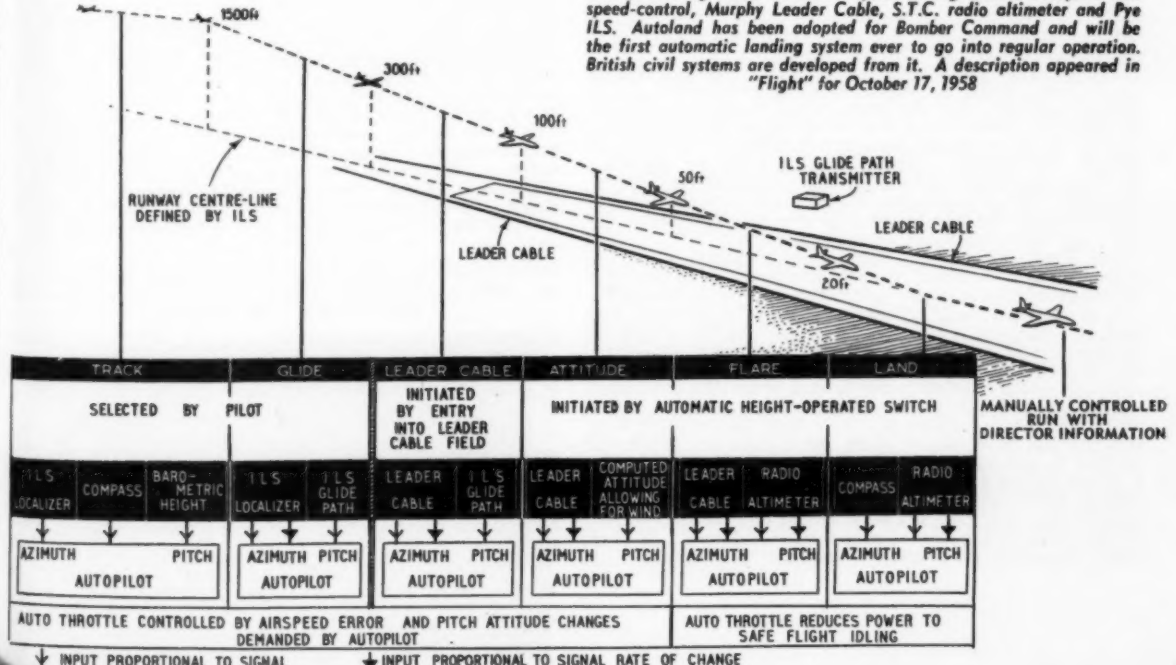
It is obviously desirable that the group of measurements chosen as the parameters for defining the approach should all be derived from one system and that their accuracy should be matched and remain reasonably constant throughout the approach. One method is a single microwave system capable of providing accurate angular and range information to be sampled in the aircraft. From this, position on the approach could be derived and almost any glide-path angle suitable for the particular aircraft computed in the airborne equipment. A conventional radio altimeter-controlled flare-out would probably be retained and the range information would provide a clear indication of the moment at which the system should be armed to switch from approach to flare-out phase. This is the solution offered by Gilfillan Regal, but it is electronically very complicated.

At present, the moment for switching to flare-out can only be judged when the radio altimeter first senses a given height above ground. With sloping or broken ground in the undershoot area this indication may be reached quite suddenly. There is a slight possibility of the flare computer being prematurely triggered if an obstacle projects close to the glide-path, but existing obstacle-clearance limits should prevent this. Smooth range information allows for some preparation, either for the pilot or the equipment, when flare-out is approaching. Altimeter limitations over rough ground might be avoided by making the equipment insensitive at heights above, say, 50ft or 150ft.

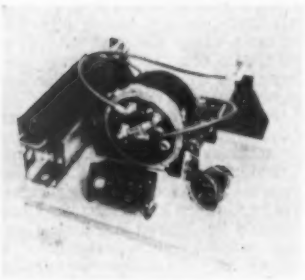
A development of GCA might allow displacement and range information to be sampled in the aircraft without the present expedients of voice or data link, but clutter at short ranges will still be a problem. A computer may be added to a lock-on radar to detect and compare the position of an aircraft with that demanded by an approach programme. The Bell ALS works on this principle and controls the autopilot by means of a VHF command link. The ground-based equipment exists at present only in single-channel form and is very expensive, but much cheaper equipment could be used to provide an independent monitor for automatic landings. Such a back-up facility will possibly be demanded for civil operations.

The accounts of ILS development work by Pye and Standard Telephones and Cables later in this review indicate that centimetric systems are being developed by these companies and that the problem of random interference with ILS is being investigated. Pye also mention a new flare-out system based on the ILS glide-path beam. One such method was suggested in America some time ago and consisted of a second glide-path at a shallower

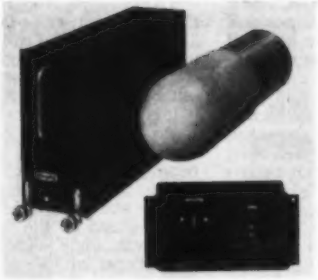
The pioneering BLEU Autoland system using Smiths autopilot and speed-control, Murphy Leader Cable, S.T.C. radio altimeter and Pye ILS. Autoland has been adopted for Bomber Command and will be the first automatic landing system ever to go into regular operation. British civil systems are developed from it. A description appeared in "Flight" for October 17, 1958



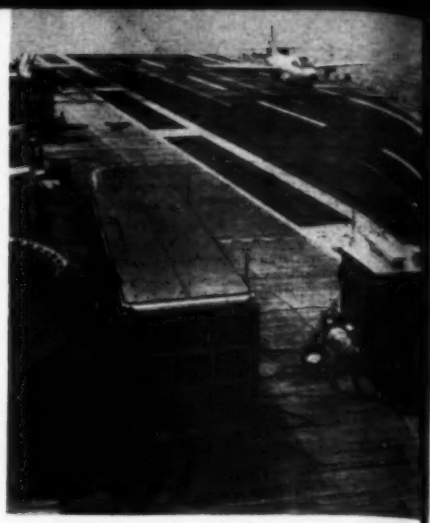
FLIGHT SYSTEM SURVEY...



A Standard Telephones radio altimeter capable of supplying auto-flare systems



Airborne units of the Leader Cable equipment produced by Murphy Radio



A Douglas F3D, under control of the Bell system, completes an automatic landing on a carrier

angle transmitted to intersect the main glide-path at a height appropriate to the beginning of the flare-out. Such alternatives are at the moment an unknown quantity.

The pilot's part in the automatic landing is generally accepted to be that of monitoring the operation with the aid of instruments which are an extension of present integrated director systems. But the possibility has been considered of keeping him in the primary loop by making him control the landing by reference to some form of pictorial indicator. The Televiewer being developed by BLEU is a particular example of this and considerable work has been done with closed-circuit television in the aircraft to establish the quality of picture which must be provided. Ultimately, Televiewer would produce a two-dimensional picture of a series of beacons along the runway, arranged rather like a flare-path. Although there are apparent advantages in overall safety and simplicity, the equipment required is complicated and expensive. Autopilots can already fly the approach more accurately and smoothly than the human pilot and there seems little advantage in retaining human control and all its imponderables.

Nevertheless, there is no intention whatsoever of displacing the pilot in his vital monitoring function. The main problem is to persuade the pilot to accept and trust the automatic equipment, especially when he knows that there is nothing he can do to correct the operation during the final phase. It is thought that it may be some years before pilots really rely on the automatics.

Other methods of controlling an automatic landing may be considered although they may raise some difficult safety problems. Doppler radar, referenced by a precise fix during the initial approach, could provide accurate groundspeed information from which range and the desired glide-path might be calculated. Conversely, a self-contained inertial system might define glide-path, course and flare-out from an initial positional reference. More likely is a compromise in which a short-term inertial system defining the approach path would be monitored by Doppler. An inertial reference operating for a matter of seconds might control the open-loop phase between 150ft and 50ft.

Take-off in the visibility minima selected for automatic landing has not been regarded as a very difficult manœuvre for the pilot to perform manually. The instruments which would in any case be provided for general procedure flying and monitoring of the landing, would inherently also provide sufficient reference for take-off. The inertial systems, however, have the additional advantage that they could also act as a monitor of take-off performance. Take-off monitoring would be even more important in visibility where the pilot might have practically no idea of the length of runway remaining ahead of the aircraft.

The actual minima in which automatic landing would be scheduled might never reach the zero-zero level because even men on foot would then be unable to find their way. In an emergency, such an operation would at least save the lives of passengers and crew, but otherwise it may well be that a reduction in minima from the present level of about 400yd to only 50yd would obviate over 90 per cent of present cancellations or diversions. The remainder would represent a tiny fraction of the total operations.

In 50yd visibility the pilot could reasonably control the landing run by reference to compass or ILS localizer. Leader Cable is an attractive and more positive guide, but it could just as well be installed in ground vehicles without encumbering the aircraft. A tractor equipped with Leader Cable receiver could go out to meet the aircraft and tow it to the parking area. Another problem in really low visibilities will be to ensure that the landing and taxying area is in fact clear of stray vehicles and people. Airfield surface movement radar could be used for this purpose. The aircraft might itself be required to carry some form of audible warning of approach to indicate its position or presence in fog.

In automating the landing in other than poor visibility, the question of the overall safety of airline flying is important. Firstly, the expense of the equipment would be more than justified if it saved one airliner. Secondly, it is important that airline accidents should not become more numerous, however much the volume of operations increases. On the basis of passenger miles, the airlines can sometimes claim a better safety record than surface transport, but not on the basis of fatalities per journey. The passenger should not be persuaded to accept a risk of accidents per journey which is higher simply because greater distances are covered. Automatic landing has a very important part to play in reducing the accident rate, as well as in increasing regularity of operation. All-weather operation is not so important to a long-range airliner as for a short-haul operator. A passenger coming from the Far East may not be so disappointed to arrive in England at Prestwick instead of London Airport, whereas one from Amsterdam could not afford to be diverted or delayed if he were counting on a day's business trip. The importance of automatic landing for the long-range aircraft is one of safety, while for the short-range aircraft it is also one of regularity.

AUTOPILOTS

THE greatly increased complexity of autopilot systems for automatic landing is not quite such a drastic innovation as might at first appear. As emphasized by BOAC in relation to the VC10, autopilot control is a requirement for normal cruising flight in high-performance jet airliners and this in itself leads to a significant increase in complexity in the form of multiplexing or duplicating. The cockpit work-load is increasing to a point where an autopilot becomes a necessity; and this equipment can in any case control aircraft better than a human pilot. The result is that pilots should be better able to adhere to stricter air traffic control demands and the more precise control of the aircraft should result in a worthwhile operating economy. In addition, if the autopilot has a high level of serviceability it can permit a significant reduction in crew complement in certain cases.

It seems that the new standard of safety and reliability now to be demanded of an autopilot system requires a quite new design approach. There must always be compromise between safety and effectiveness in the matching of the autopilot to a particular aircraft. Specific requirements are laid down to define the degree to which the most serious failure case, a runaway in one or other

Smiths autopilot for BLEU Autoland. Left to right, the servo control unit, platform control, locking unit, a control servo and the test meter. Behind the servo is the pressure unit

axis, can be allowed to affect the aircraft. Complementary stipulations are made to determine the minimum height above ground at which the autopilot may safely remain engaged.

The requirements in fact state that, in the pitch axis, a runaway must not produce a normal acceleration increment of 1g negative or greatly exceeding 1g. In the roll axis, an aileron runaway for 5sec in cruising flight must not produce more than a given bank angle; and there is an additional limitation in height loss and lateral divergence from centre-line following a 2sec runaway on the approach. In the yaw axis, the worst runaway is that in which the rudder moves at maximum rate to the greatest angle which can be achieved by the autopilot, the rudder deflection being held while the aircraft yaws. Considerable over-swing will inevitably occur, and it is assumed that the rudder is released as the peak yaw angle is reached, at which point the maximum fin load will be developed. The resultant load must obviously not exceed the proof load of the fin.

In traditional single-channel civil autopilots a variety of devices have been applied to limit the authority of the autopilot servos to meet the above requirements. The task has become increasingly difficult, partly because the performance of aircraft has been continuously advancing and partly because it has proved more and more difficult to provide adequate limitation of authority for one flight condition without rendering the autopilot almost useless in another flight condition.

The usefulness of conventional limiting devices is now greatly reduced and time has come when a rather different approach is needed. Torque limiting devices, control surface-deflection limit switches, g switches and the like are becoming less and less useful as safety solutions. The method chosen by Smiths is a multiplexed autopilot in which a number of autopilot sub-systems operate continuously in parallel. Provision is made either to disengage the complete autopilot following a failure in one of two sub-systems or that the remaining effective channels in a group of three or four sub-systems will be able to overpower one malfunctioning sub-system. Elliott Brothers (London) Ltd have chosen a very different solution in which fully duplicated autopilots are each provided with a comparison monitor. One autopilot is regarded as a stand-by for the other and either manual or automatic change-over is provided according to whether the system is designed for cruise and approach only or automatic landing as well.

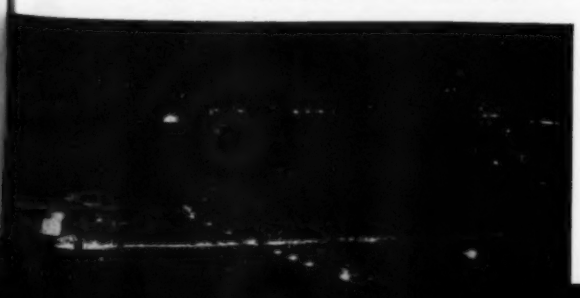
VTOL AND AUTOMATIC LANDING

IT must be assumed that helicopters and other VTOL and STOL types with special approach characteristics will operate in low weather minima, the helicopter being the first type to enter regular service. Serious consideration has already been given both in Britain and America to all-weather helicopter flying and Bell helicopters are in process of developing a very advanced and elaborate pictorial blind-flying system. Some time ago they also carried out extensive trials of pin-point landings using a range of equipment including Decca navigator, the Bendix sonic altimeter and the Kenyon transitometer (*Flight* for May 10, 1957).

The BEA Experimental Helicopter Unit has for some years been approaching the problem in conjunction with BLEU with rather less elaborate equipment. Actual blind landings, using only Decca large-scale Flight Log charts were made in a Sycamore some six years ago, but much additional equipment has since then been introduced and development still continues. In one direction, visual references have been greatly improved by a new lighting pattern for night landing which was demonstrated at Gatwick and described in *Flight* for April 11, 1958. The Thorn red/white visual glide-path indicator system has also been added to the lighting at Gatwick.

While these aids improved direct visual reference, some form of radio guidance is required for actual blind approaches and some steps have to be taken to make the inherently unstable helicopter easier to fly under instrument conditions. To this end, BEA have been evaluating a Sperry Zero Reader modified to accept additional signals from three rate gyros and cyclic stick-position. An i.a.s. term will be added to assist speed control. This will presumably form the basis of an integrated instrument display and will lead in due course to an autopilot approach coupler. An automatic, programmed transition mode would be provided in the autopilot so that, at about 150ft, glide-slope control would be released and the transition made to the hover under localizer control alone. Collective pitch control would be automatic in this phase. The Whirlwind helicopter now being used by BEA for these trials is fitted with the Newmark helicopter autopilot providing short-term, three-axis stabilization with the pilot's demands superimposed on the stabilizer signals; or long-term stabilization from a gyro vertical; or a hover mode in which compass signals are introduced to maintain heading in a stable attitude at or near the hover. Collective pitch is manually controlled throughout.

A Westland Whirlwind of the BEA Experimental Helicopter Unit landing at night on the lighting pattern of Gatwick heliport



For city centre operations or in areas where there are several heliports close together, it is considered that the instrument approach area of a particular heliport should not extend over a radius of more than one mile from the landing site. BEA have established the optimum glide-slope angle at 20° and have made such approaches using Decca or a slightly modified standard ILS. The principal unfulfilled requirements are an accurate height indicator suitable for helicopters and some form of groundspeed indicator. For various reasons noted below existing equipment is not entirely suitable. Nevertheless BEA have shown that blind landing for helicopters in only relatively unobstructed sites is possible with existing equipment although it requires a degree of training and skill. BEA certainly have more practical experience of such operations than any other organization. A report in *Flight* for January 8 gave the following account of a demonstration flight with Capt Reid of the BEA experimental helicopter unit in Whirlwind G-AOCF at Gatwick.

"The first approach was made visually on a 20° glide-slope defined by the two Calvert red/white VGPI lights located beside the cross of Lorraine pattern of high- and low-intensity lighting, the let-down being started from 1,200ft. The 20° slope looked more like 45° from the cockpit and very good downward visibility is necessary to keep the lights in sight. VGPI reference was lost at about 150ft, but by that time the transition was beginning. We next made a 15° approach on the lighting pattern, using Decca Mk 8 and a large-scale chart as the only reference. Chart markings showed the extended centreline and reference heights every 100ft, to which Capt Reid adhered expertly to arrive exactly over the pad.

"Visibility minima established at present are 200ft and 400yd with Decca and 80ft and 150yd with ILS. The slender width of the pen-line on the Flight Log may represent an unacceptable error when a touch-down must be precise. Decca approach information could be presented on an ILS-type cross-pointer, but some complication would result if the approach were not substantially parallel to the lattice lines. It is intended that the instrument approach area round a heliport should extend over a circle of only one-mile radius to avoid interference between neighbouring sites.

"One of the main problems in actually making these approaches lies in wind effect, both on groundspeed and on drift. When approach speeds are as low as 30kt drift may well be up to 40° and wind-shear and gradient greatly affect glide-slope performance. IAS is relatively unimportant, because the helicopter (unlike a fixed-wing aircraft) is in no danger of stalling, but groundspeed is all-important in maintaining descent angle. The lighting pattern must be embedded (and therefore fixed) in the landing area and the pattern can at best cover four approach directions, so cross-winds will inevitably occur. The transition from near-autorotative descent to hover, which is a difficult helicopter manœuvre even in visual flight, must be made accurately into the ground-cushion and over a limited ground distance. Some accurate height-reference is desirable, but both the radio and sonic altimeters now available are likely to become inaccurate over built-up or undulating ground. Doppler suffers similarly.

"In the new turbine helicopters constant-speeding will greatly ease collective-pitch control and sufficient power will be available to hover safely at over 100ft, virtually out of ground-effect. In these circumstances a barometric altimeter may offer a sufficiently accurate height indication. Piloting may also be simpler if it is possible to separate cyclic and collective control to make the former govern speed and the latter descent gradient."

BEA's efforts have recently been directed to establishing the equipment to be carried in the Rotodyne, in which 550lb are allowed for control and navigation equipment. Such provision is extremely important for a machine like the Rotodyne because profitable operation will depend to a great extent on the degree of regularity which can be achieved. The kind of passenger who decides suddenly to make a Rotodyne journey and simply goes to the heliport and buys a ticket will probably provide a significant proportion of the traffic. He would be seriously deterred if cancellations because of weather were frequent. The equipment carried in the Rotodyne will probably include duplicated autostabilizer and a single autopilot, together with integrated director instruments. Also carried will be ILS, duplicated VHF radio, intercom and cabin address, and navigation aids chosen from Decca, VOR or ADF, and possibly a precision altimeter and a high-definition search radar.

C. M. L.

FLIGHT SYSTEM SURVEY

BEA AND AUTOMATIC LANDING

D.H.121:

Pt. 1—The Operator's Viewpoint

ONE of the clearest statements of BEA's requirement for automatic landing was made by Lord Douglas of Kirtleside, the chairman, in the BEA house magazine in November 1958.

"In future, all airlines must reduce the effect of weather on their operations. This objective is particularly important to BEA because, as an exclusively short-haul airline, we have to make more take-offs and landings than our competitors—a large number of them in bad weather. The resulting lower punctuality and regularity substantially increases our costs, as well as reducing the standard of service we are able to offer the travelling public. Furthermore, the highly seasonal nature of our traffic is partly due to this same lower punctuality and regularity in the winter months. If we could improve these, we ought to be able to increase our winter traffic quite substantially and thus reduce our peak/trough problem, to the great benefit of our financial results.

"For these reasons, I believe BEA must make every effort to get automatic landing equipment installed in its next generation of aeroplanes, even if use of the equipment is not possible at first right down to 'zero-zero' conditions. A technical and operating problem of this magnitude cannot be solved in a single step nor by the airlines alone. The co-operation of airport authorities, research departments and companies interested in the development of the equipment is essential. I hope we shall be able to get down to such discussions in this country before long. . . ."

As if to emphasize Lord Douglas' words, the weather during succeeding months turned foul, as many people still vividly remember. In fact, Lord Douglas wrote in the February 1959 issue of the BEA house magazine in these terms:—

"I referred last month [January] to the adverse effect of recent bad weather on our financial results. Since those words were written we have had yet another month of bad fogs. In January, no fewer than 550 of our services had to be cancelled because of the weather, bringing the total of weather cancellations for the three months from November to January up to 1,370. This has, in fact, been the worst winter in BEA's history, from the point of view of traffic lost as a result of the weather. During the three months the weather at London Airport, for example, was below BEA's operating limits for no less than 13 per cent of the time, equivalent to a total of nearly 12 complete days. The fog has, in addition, been unusually widespread and has affected the whole country, particularly the Manchester and Glasgow areas which are important BEA traffic centres.

"The financial loss to BEA as a direct result of fog so far this winter is estimated at about £200,000. Of course, the actual revenue lost was much greater than this, but was partly offset by savings in operating costs. In addition, there are undoubtedly indirect losses which are impossible to estimate. These heavy losses, which may well mean the difference between a profit and a loss for the corporation in the 1958/59 financial year, underline the vital importance of the weather problem to BEA.

"There are two ways in which this weather problem can be tackled. These are: (1) To install FIDO—fog dispersal apparatus—at London Airport. (2) To adopt automatic landing equipment.

"The position on these two developments is that the RAF are now testing a trial installation of the latest type of FIDO and we hope to obtain Government agreement to a complete installation at London Airport as soon as the effectiveness of the new design has been proved by the trials. This means that if sufficient urgency is applied to it, we might hope to have FIDO working at London Airport within, say, two years.

"Automatic landing is, I am afraid, much further away. If all goes well with the development of the equipment which we will be ordering for our new aircraft, we should be able to start using it on a limited scale from the mid-1960s and we might perhaps hope to have it in general use on all our aircraft within ten years.

"In other words, FIDO is the only possible early solution to our weather problem. It cannot be a complete solution because, on account of expense, it will probably be possible to have it only at London Airport; but I am convinced that an installation there, at the heart of our network, could have a profound effect on our operations in bad weather. Moreover, although FIDO can be an early solution, I do not believe that its usefulness will disappear when automatic landing does eventually become available. It will, I believe, continue to be required as a standby in the event of emergency or failure of the automatic landing systems."

FIDO had, in fact, been considered some time before this and the BEA annual report for 1957-58 recorded that the corporation had "reiterated its wish that a major effort should be made to hasten the time when a practical system of fog dispersal will be available on our main airfields, especially at London Airport." MoS and MTCA were keeping BEA informed of the latest progress in development of heating techniques (FIDO) and chemical methods. But, as it happened, FIDO fell by the wayside for a number of reasons, not necessarily connected with its ability or inability to perform the fog-clearing function.

As background to the November 1958 statement, Lord Douglas recorded that the demonstration of the BLEU Autoland system during the previous month "had aroused renewed interest in the possibility of airline operations independent of weather." BLEU had solved all the basic problems so that the first steps towards all-weather airline operations could be taken, but many problems remained, particularly in ensuring that some agreement was reached internationally on the form the related ground equipment should take.

From the foregoing remarks it is evident that BEA has a clear-cut economic requirement for all-weather operation and that this calls for an automatic landing system. A significant point is that a large part of the requirement would be met if London Airport alone were equipped for such operations. Almost all the corporation's aircraft are based there and regularly return there, either during routine operations or for servicing, and it would greatly help the planning of poor-weather operations if aircraft could get back to London with certainty, even if it were only for maintenance or positioning and not necessarily with a passenger load. To a certain extent, therefore, BEA could rely on equipment not internationally standardized and remain unaffected by such standards. The introduction by BEA of automatic landing is thus not necessarily tied chronologically to definition of a standard and its subsequent implementation. Nevertheless, BEA will obviously not ignore such standards.

Like BOAC, BEA ordered a new jet airliner at about the time when the BLEU system was demonstrated and they were able to make the decision to provide for such operations from the outset in the basic systems design. De Havilland, Hunting and Fairey, grouped as Airco, are now engaged in designing the D.H.121 and the special flight control equipment has been entrusted to Smiths Aviation Division, who are being assisted by Sperry and Kelvin Hughes. Standard Telephones & Cables are to supply the radio altimeter for the flare-out manœuvre.

BEA and the manufacturers have combined to produce this refreshingly new cockpit layout for the D.H.121. It is designed for three-crew operation with all three looking forward for the first and last ten minutes of each flight. The roller-blind principle now applied to new Service attitude and directional displays is applied to the flight-system instruments, with directly operated stand-bys above the central navigation display. Engine instruments are displaced to starboard. A central warning panel is at right centre, with the weather radar at left centre. The flare-out indicator above each flight system is flanked by attention-getting lights. Further details are given overleaf

D.H.121: Pt. 2—Smiths Aviation Division

WITH the very considerable background of co-operation with BLEU in development of Autoland as well as of the design of both civil and military autopilots culminating in the SEP.2, Smiths Aviation Division can be assumed to have a commanding lead in the civil automatic landing field. Although the company is very much keeping its own counsel, for competitive reasons, an incident which occurred only three weeks ago indicates the level of achievement they have now reached.

On a day when fog had dislocated road traffic in the area, a Varsity operated by Smiths landed at Hatfield under fully automatic control. The visibility was estimated by personnel on the ground to be approximately 50yd, which was confirmed by observers at the beginning of the runway who heard but did not see the aircraft pass. Hatfield, of course, has no Leader Cable but it has the latest Pye ILS and good site conditions. Asked to confirm this incident, Smiths stated that "as part of general development of equipment a number of automatic landings are made in low visibility including fog, with design personnel on board to enable them to give a true assessment of the problems involved. On this occasion, the design personnel were dropped off at Hatfield at the completion of the exercise."

The significant fact about this incident is that an aircraft of the size and performance of the Varsity is being used for fully automatic landings in such visibility, not at one airfield and in ideal test conditions, but at a constructor's airfield with less facilities than an average international civil airport. This says a great deal for the equipment itself and for the confidence which the pilots have in it. Later on in this review, Pye's own statement on the development of their ILS system records that more than 200 automatic landings using only ILS without Leader Cable have been made.

Whatever may be the intrinsic disadvantages of ILS as the basic guidance element for automatic landing, the ICAO standard safeguards the system until 1970 and there seems to be a good prospect that this protection will be extended. Smiths' advantageous position in automatic landing development is doubly significant in that they co-operated in the earlier BLEU work using ILS and Leader Cable, but have also used ILS alone.

Unfortunately, Smiths are not prepared to reveal what kind of equipment was installed in the Varsity alluded to above, nor are they willing to describe in any detail the equipment intended either for the auto-flare or for the automatic landing stage in the D.H.121.

Nevertheless, it has been stated that the company is firmly in favour of a multiplexed control system in an aircraft involved in automatic landing. The problems of suitably limiting autopilot authority in the interests of safety without rendering the autopilot ineffective in certain flight conditions are thought to have become virtually insuperable in view of the performance of modern airliners and the great variety of flight conditions under which the autopilot will be called upon to operate. Duplication of more or less conventional single-channel autopilots can increase reliability, but does not necessarily overcome the difficulty of authority-limitation. Smiths have therefore chosen the multiplexed arrangement in which a number of autopilot sub-systems operate continuously in parallel.

Following detailed study, Smiths have come to the conclusion that a duplexed arrangement with two sub-systems provides adequate safety at a satisfactory level of authority for normal flight conditions but, because the malfunctioning of one sub-system leads to a cutting out of the autopilot in that axis of control, the duplexed arrangement is unsuited to automatic landing in blind conditions. The triplexed system, with three sub-channels for each axis, is arranged so that, in the event of failure, a malfunctioning sub-channel will in the first place be overpowered by the two good ones and thereafter be cut out. Provided that each sub-channel is sufficiently powerful to control the aircraft by itself and that a normal degree of component reliability is achieved, the triplexed system is considered by Smiths to be suitable for use during an automatic landing.

If three working sub-systems are considered necessary for automatic landing it follows that some allowance must reasonably be made to ensure that all three are working when the approach is begun following a long flight. If automatic landing is established as a scheduled part of each flight it seems that three working sub-systems at the beginning of the approach can only realistically be guaranteed by the provision of suitable redundancy in the form of a fourth sub-system.

Yet consideration of the number of sub-systems must extend beyond the autopilot itself. A triplex system would surely be put out of commission as far as automatic landing was concerned if the aircraft carried a single ILS receiver and this failed during the approach. Multiplexing also becomes necessary in related equipment such as instruments, sources of air data, gyros, control surface-actuation and the supply of electrical and hydraulic power.

The considerable additional expense of providing this level of redundancy throughout the aircraft need not be considered a direct penalty of automatic landing itself. As explained elsewhere in this review, autopilot control is now required throughout the flight; and some form of multiplexing or multiplicating is necessary in a powered control system without manual reversion.

In addition to providing the autopilot for the D.H.121, Smiths have produced the automatic throttle control equipment for Autoland and will presumably do so for the D.H.121 as well. Again, automatic landing equipment inevitably involves considerable work on the flight instruments with which the pilot must be able to monitor the automatic operation. The extent of the company's work in this direction can only be guessed at and further details are given in the discussion below of the D.H.121 itself.

D.H.121: Pt. 3—Airco

BY any standards, the D.H.121 is a remarkable project—and it becomes more interesting the more closely one examines it. As a very fast transport designed for intensive operation on short routes it presents many new problems both for the designer and the operator and Airco and Smiths between them have arrived at some solutions which are little short of revolutionary.

Ordered initially for BEA's specialized network, it follows more closely than any other type the new thinking on flight controls and autopilots which is set out in this review. The aircraft and its basic systems have been very considerably affected by the control philosophy outlined in the account of Smiths thinking above—as indeed they must if the new concepts are to be carried to their logical conclusion. Triplexing of an autopilot is of no use if other elements in the overall control chain remain in traditional form

SYSTEM SURVEY...

and can, by failing, put the whole chain out of action at a critical moment.

At an early stage, de Havilland decided to apply fully powered flight control without manual reversion and also to use a single-piece horizontal tail. The latter, in fact, carries a geared elevator-like surface, but this is not separately controlled and moves in direct relationship with the tailplane. Because of these decisions some form of multiplexed powered control system has been required and resulted in a triplex layout in which each engine drives a pump serving a separate hydraulic system, two of which feed the utilities as well as two control channels. Each control surface is therefore to be operated by three actuators (made by Fairey) each supplied from a different hydraulic system. In case of pump or engine failure, any one of the three systems may be restored to full pressure by an electrically-driven pump and, as a second stand-by, a ram-air turbine can be extended to perform the same task in the remote case of all three engines having failed.

The electrical system is similarly based on three a.c. alternators, each driven by one of the engines, and each supplying one flight system. The whole may be operated either as a triplexed or as a triplicated system. Emergency d.c. supply and an inverter are included.

There is therefore full provision for triplex controls, electrical system, flight-instruments and radio in the basic design. The triplex autopilot, which can be provided for the automatic landing stage, will naturally fit in with this arrangement. It has been stated that the initial stage of auto-flare would probably be accomplished with a duplex autopilot, but full provision is made for subsequent up-grading of equipment for the more advanced operation.

Auto-flare should enter service in the D.H.121 during 1964 and a period of crew familiarization and fault-clearing will follow. After that, weather minima might perhaps be reduced to something below the present level of 200ft and 0.5 mile. Subsequently, the equipment will be upgraded for automatic landing and a further period of familiarization would be required. The target for the establishment of automatic landing as a routine manœuvre in service is stated by de Havilland to be 1970. It is remarkable that this is some 11 years after the RAF adopted Autoland.

Human reaction to automation of the landing in low visibility is a major factor in the introduction of the equipment, because each pilot must be persuaded that he is justified in committing himself and his passengers to automatic operation which he can do very little to correct if something goes wrong in the critical final stage. He must be convinced that the equipment is in fact safe and also that he can effectively monitor its operation down to that last critical stage. Provision of suitable instrumentation is one part of this task, but neither Smiths nor de Havilland have revealed very much about their plans in this direction. But it has been strongly emphasized that monitoring must be possible and that the whole operation must be a "simple and unfrightening" process for any pilot.

From information released about the auto-flare stage it can be deduced that a normal coupled ILS approach will be flown by the autopilot down to a height of about 150ft, at which most present glide-paths become inaccurate or too sensitive. The autopilot would then provide open-loop guidance in pitch, maintaining an attitude which has been averaged during the preceding approach phase. At about 65ft, signals from duplicated radio altimeters would trigger the auto-flare stage and provide information to a computer to control the flare-out on to the runway. Smiths have shown that throttle setting can significantly affect the flare-out control of the autopilot and that automatic control would be necessary. Such a device already has been produced for BLEU Autoland and would be applied to the D.H.121 to maintain airspeed within ±2kt of a preset value during the approach. During flare-out it would reduce power to flight idling at a predetermined rate. The pilot would control ailerons and rudder to line the aircraft up visually with the runway centre-line and to kick off drift.

Airco have stressed that for both economic and technical reasons no ground equipment other than ILS should be required. This almost certainly means that for automatic landing one of the new, more accurate ILS systems would be needed.

Although virtually nothing has been said about the instrumentation of the D.H.121, an inspection of the mock-up cockpit for BEA (see page 239), reveals quite a new approach to cockpit layout. Basically, the flight deck is laid out for three-crew operation, with the provision that all three men should be seated looking forward during the first and last ten minutes of every flight. While the third man normally supervises the systems panel behind the co-pilot in cruising flight, he moves his seat up to the end of the central console during landing and take-off. Any system failure will be indicated to the crew in the forward field of vision, and particularly by a centralized warning panel containing illuminated notices. Red and orange attention-getting lights are located directly in front of each pilot. Failures requiring urgent action are denoted by the red lights and those less urgent by the other. Trim, throttle, radio, and utilities controls are conventionally placed on the central console with further controls, including the selectors for the three hydraulic systems, in the roof.

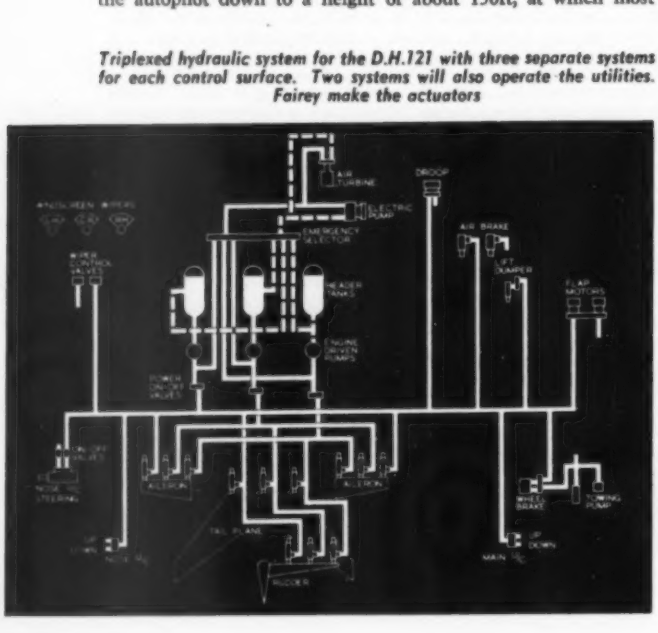
It may be deduced that several air data computers and gyro references are provided to supply the two flight-instrument groups on the panel and the autopilot system. Needle-and-counter altimeters are servo-operated and the single a.s.i. pointer revolves over a logarithmic scale through two complete turns. ILS information is presented on each flight system and there is a third, miniature cross-pointer instrument beside the captain's panel. In the same way, there is a radio-altimeter dial over each pilot's panel and a third such instrument near the captain. Of the three needles on these dials, one appears to be an indicator and the others are yellow markers for significant heights. The height scale reads from 0 to 700ft. The VSIs, incidentally, are of a type not seen before, reading logarithmically up to 7,000ft/min up or down.

Perhaps most significant are the central flight system instruments themselves. They are evidently based on the roller-blind, remote-operated principle which has been adopted by the RAF. The attitude presentation includes a director symbol and several prominent warning flags. Beneath this dial is the compass display with conventional compass graduations round the rim and a steering director or course-selector mark. The centre of the instrument is taken up by a further roller-blind display on which blue and yellow areas obviously represent the ILS blue-yellow sectors and provide localizer guidance. The RAF roller-blind compass display can be shifted to display ILS or Tacan navigation information and it seems certain that the instrument seen in the D.H.121 mock-up provides similar facilities.

Because all these instruments depend on remote sources of computed information, a conventional directly-operated a.s.i., electric horizon and three-pointer altimeter are provided as stand-bys at the top of the central panel. A miniature turn-and-slip instrument is nearby. The nine basic engine instruments are grouped within a white outline to the right of the central panel.

Another significant feature of this new cockpit is the fact that the central panel space which traditionally has been occupied by engine instruments is taken up by a pictorial map display. Unlike the Decca Flight Log, this map is square and can therefore display a greater area ahead of the aircraft— a useful asset for high-speed flying. DME and ADF instruments are located immediately to the left of the map, together with Doppler navigator indicators. It seems possible that it is intended to drive this map mainly from the Doppler output, using periodic fixes from the other aids to correct any errors which might build up. Weather radar indicator and controls are mounted together above and to the left of the map.

It is remarkable that, despite triplication of so much of the basic equipment and the addition of some entirely new elements, the cockpit should still appear neat and uncluttered. For the first time a new aircraft more complicated than its predecessors has been given a main instrument panel which appears significantly less complicated than earlier examples. Great credit must go to BEA, de Havilland and Smiths for achieving this result.



Triplexed hydraulic system for the D.H.121 with three separate systems for each control surface. Two systems will also operate the utilities. Fairey make the actuators

SYSTEM SURVEY...

BOAC AND AUTOMATIC LANDING

VC10:

Pt 1—The Operator's Viewpoint

LIKE many other operators, BOAC have always considered that automatic landing would be developed for airline use. Since the late 1940s the departments concerned with flight operations and development have been carefully watching any activity which gave promise of achieving such performance. They had followed BLEU work at Martlesham Heath, Woodbridge, and later at Bedford, but for many reasons it was not until the later 1950s that automatic landing looked like becoming a practical possibility. Information about the Bell Automatic Landing System was first published early in 1957 and, in mid-1958, BLEU were able to release details of the single-channel system which has been called Autoland and to offer it as a basis for civil equipment.

One significant retarding factor was the slow implementation, in early post-war years, of ILS. Now taken for granted, ILS is still the basis of the first stage of automation; without it, progress towards that goal was unthinkable. In 1950 and 1951, BOAC needed ILS for their first Comet operations, but London Airport was almost the only airfield on the African and Far Eastern routes which was so equipped. Even now, ten years later, implementation of this ICAO standard is by no means complete and the best of installations does not yet provide for 100 per cent operation —a condition which is obligatory when a full automatic landing is being conducted and which is not met by the normal standby equipment.

The provision of known equipment continued in parallel with the development of the new automatic techniques; and commercial operators at the same time were beginning to use ILS couplers in their autopilot systems to provide automatic approaches down to about 200ft.

At the time when the second automatic step of auto-flare looked as if it could be introduced into service in a measurable number of years, BOAC were considering the Vickers VC10, an aircraft which would enter service in 1963-1964 and, more important still, would subsequently remain in service for ten years. Because of the time scale it was important to consider whether auto-flare should be taken into account in specifying the equipment for this aircraft.

There were in fact two major considerations for BOAC to take into account when they began to specify VC10 equipment shortly after the contract was signed late in 1958. Firstly, BOAC decided that the autopilot should be considered essential in the en route case and the likelihood of any unserviceability removed. At 40,000ft, an airliner must be flown on instruments, but the pilot's energy should not be taxed at this stage when his full ability must be available during the more critical descent and landing phase. An autopilot can in any case control the aircraft better. In order to ensure the highest degree of autopilot service throughout the flight a duplicated installation appeared to have great advantages. Secondly, it was clear that a duplicated autopilot would give much greater scope for development of the auto-flare rôle with progress towards full automatic landing. For these dual reasons BOAC decided to accept the very considerable expense of fleet-wide autopilot duplication. The equipment is being made by Elliott and is similar to the Bendix PB-20 installation in the BOAC Boeing 707s.

It is interesting to note that the reasoning outlined above does not include the hope that auto-flare will immediately improve regularity of operation. BOAC consider that it is extremely difficult to define this factor in terms of economics and that no really appreciable profit could be shown until the full automatic landing has become so established that a reduction in the diversion fuel allowances can be made. It will be some time before a pilot could be persuaded to leave behind all or part of his fuel reserve and count on a certain arrival at destination using automatic equipment regardless of visibility.

Crew psychology is indeed a major factor in almost any stage of automation, either during approach or landing. BOAC's first operational experience of approach couplers was in the Stratocruiser in 1950 and all their aircraft are now so equipped. But, even now, automatic approaches are by no means regarded by the pilots as completely routine, even though the equipment performs according to specification. Pilots frequenly prefer to make an instrument approach manually in order to maintain their proficiency—not necessarily because they dislike automatics.

BLEU had clearly demonstrated that auto-flare and automatic landing techniques were sufficiently established to justify civil operators in planning on such equipment. The dual autopilot was decided upon for the reasons outlined above, but BOAC then set its sights at a practical level and decided to implement first the auto-flare stage which they expect to be achieved without any additional ground equipment. Auto-flare was in any case a most important first step towards automatic landing and that part of the operation had to be proved in service at an early stage. It was reasonable to suppose that if the autopilot could fly an aircraft better than a human pilot in the cruising condition, it could also better control the flare-out.

As far as full automatic landing is concerned BOAC appear to have gone no further than to take a front-row seat in order to watch developments. They point out that although auto-flare is extremely expensive it can provide some immediate benefits. Any operator who equipped his aircraft for automatic landing now would be unable to derive due profit from the equipment until the necessary ground installations had been provided and all the preliminary trials and familiarization completed.

A major factor is that of international standards since there is no guarantee that, when ICAO comes to consider this point, as it inevitably will, an American system will not be chosen in preference to equipment developed in Britain. Such a choice might more directly affect BOAC than, for example, BEA, because of its worldwide operations and its consequent dependence on a great number of foreign governments for infrastructure.

BOAC feel that to solve the auto-flare problem would be a real advance in itself. It is also a simpler proposition from the certification and reliability point of view. Auto-flare is not likely to allow any great decrease in weather minima, but it could improve landing accuracy to a point where the aircraft manufacturer or the operator would benefit from shorter landing field-lengths. Being in effect an extension of the coupled ILS approach, it would present fewer difficulties from the human point of view and could be used or not for any particular landing. For monitoring, the pilots will need only the director instrumentation already destined for the aircraft and will in any case be able to verify performance by visual reference to the ground.

BOAC point out that automatic landing in zero zero weather would be of limited value unless all the supporting ground facilities could operate under these conditions and the aircraft could also take off again. This is something of an illusory benefit and may not in fact become important for some time and perhaps not until supersonic airliners are introduced. In the meantime, they hope that auto-flare will prove adaptable to modification to automatic landing in whatever form it is internationally agreed.

FLIGHT SYSTEM SURVEY...

VC10: Pt 2—Vickers-Armstrongs

PERHAPS the most significant fact in the Vickers design of the VC10 transport for BOAC is that the control systems first planned for the aircraft have been altered relatively little to meet the extreme safety requirement for auto-flare. Whereas fully duplicated flying controls would have satisfied airworthiness requirements, Vickers chose right from the start to apply at least a triplicated system. Power supplies to some portions of the system are hydraulic and others electric, the failure of electrical supply leaving hydraulic units operating in the same plane, and vice versa. Mechanical control runs are fully duplicated. Following BOAC requirements, duplicated autopilots are to be fitted and provision is being made for automatic changeover from one to the other. An exhaustive programme of rig testing has been planned so that eventually the combined flight control and autopilot system will be proved in a complete full-scale rig at Weybridge.

Having already provided in the primary concept for a level of safety thought to be sufficient for auto-flare, the addition of the specialized equipment for this operation is relatively straightforward. It is hoped that automatic landing will not prove more difficult to accommodate, but there are a number of additional factors to be considered—for example, shall the automatic landing also include control of the landing run and taxying? And will automatic braking and nosewheel steering be required? As far as possible, allowance has been made for new ground equipment which may in future be produced.

First details of the control system layout were given in our Farnborough Review issue of September 18 last. It is based on a fully powered system without manual reversion, using self-contained power control units designed by Boulton Paul and applied to separate sections of the split flying-control surfaces. Hydraulic pressure is raised within the power unit by a variable-stroke hydraulic pump driven by an electric motor, the pump being set to zero output when the control is stationary. Because the hydraulic system is self-contained in each unit, the only supply from the aircraft to the power control units is electrical. Any failure in one unit will disable only one of several control surfaces in any one axis, leaving the others still in operation and capable of supplying the necessary control effort. Spring links at each power unit prevent a failed unit "freezing" the control linkage.

Vickers carried out an exhaustive investigation of the relative merits of control systems with and without manual reversion and finally decided that the power-only approach was the better. In particular, something like 1,000lb in weight was saved by the elimination of mass- and aerodynamic balancing and highly stressed control runs. The split-surface approach has in fact resulted in three rudder sections, four elevators, four ailerons and six spoiler/airbrake sections.

Rudder, elevator and ailerons are operated by Boulton Paul power control units which are supplied from the aircraft electrical system. The variable-incidence tailplane and spoilers are supplied from the aircraft hydraulic system, the former being operated by hydraulic motors and the latter by Boulton Paul jacks. The mechanical control runs are duplicated in order to provide for the eventuality of a fractured cable, as shown below.

There are two separate engine-driven hydraulic supplies with a ram-air turbo pump as a further stand-by for one of them. Two hydraulic motors, one fed from each system, drive a screw-jack individually or together to adjust tailplane incidence. Moreover, the motors are individually controlled from levers located in the cockpit, respectively close to the captain and co-pilot. Each lever is flanked by another which arms the control circuit. Without this the circuit is dead and an inadvertent runaway cannot occur. A third pair of levers near the captain is connected by shafting to the co-pilot's levers to enable the captain to retain control over the tailplane in the event of a failure of the system operated by his normal levers. If necessary, the pilot can operate both motors together by moving both pairs of levers and obtain twice the normal rate of tailplane movement. Lever deflection governs the rate of movement, the extent of movement being indicated on a dial. Maximum rate with a single motor is ¼°/sec.

Hydraulic supplies to the two actuators which move each spoiler surface are so arranged that, should one supply fail, the two middle surfaces are disabled and if the other supply fails the other four surfaces are affected. The VC10 has two a.c. electrical systems which may be switched to operate separately, but which normally run in common in order to avoid excessive load-shedding in the event of a failure in part of the system. There are thus two distinct sources of electrical power to apply to the various Boulton Paul power control units at ailerons, elevators and rudder.

Artificial feel is by Hobson packaged hydraulic feel units for all three axes connected to the base of the control columns by mechanical linkages. These are basically q-feel units, but incorporate combinations of altitude capsules and/or springs to obtain the required feel characteristics at all speeds and heights. The feel units are duplicated and so linked that if one fails, the other provides the full reaction. Feel appropriate to about 100kt i.a.s. will be provided at this and lower speeds.

The elevator surfaces are mounted on the tailplane and therefore move when tailplane incidence is adjusted. Because the feel datum is fixed, feel forces will tend to align the elevators with the tailplane, so that the pilot will trim this surface to relieve stick forces in steady flight conditions. In so doing, he will tend to keep the elevator-to-tailplane angle at datum value. The control column will thus be centred in any trimmed flight condition and the feel load will be relieved. The pilot will make the initial tailplane incidence setting as part of his pre-take-off vital actions.

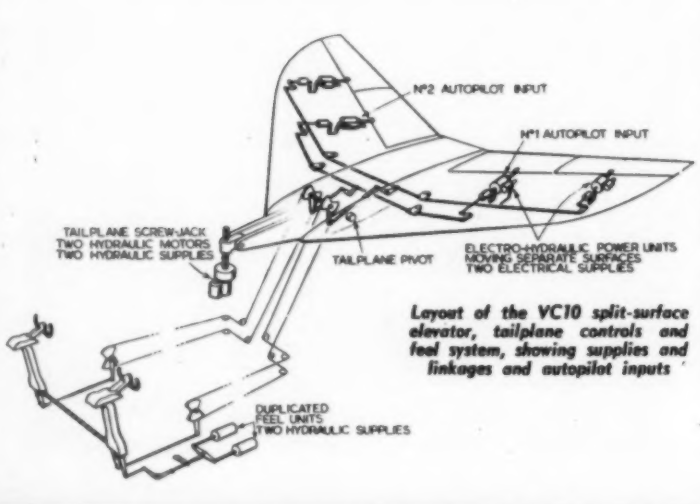
The foregoing description gives some idea of the extent of multiplicity and redundancy provided in the basic VC10 control system. Although Vickers point out that they chose this arrangement without regard to the eventual autopilot system or the auto-flare requirement, it does in fact satisfy the very stringent requirement which automatic systems raise. Duplicate autopilots have been integrated with the basic controls and autopilot demands are introduced by small electric torque motors mounted on certain of the Boulton Paul power control units and operating the normal control valves. In this way the need for separate autopilot servo-motors capable of reacting feel loads and operating the long control runs has been eliminated. All three axes are autopilot-controlled.

A monitor is applied to each autopilot so that a malfunction will cause automatic disengagement leaving the aircraft under manual control until the second autopilot is engaged.

In the elevator channel, the No 1 autopilot signal is applied by a torque motor on the port inboard power control unit, jack movement being fed back into the primary control runs to move the remaining surface sections and the control columns and thus obtain feel reaction. Certain mechanical actions are performed to lock the control linkage to ensure this feedback; and a spring strut in the circuit will yield beyond a given feel reaction level to form a mechanical torque-limiting device. This forms a final safeguard or "long-stop protection" which is additional to the limitation built into the autopilot itself. By this means the effect of short-term disturbances is reduced and nuisance cut-outs in the autopilot should be avoided. The mechanical torque limiter does not prevent full control deflection at low airspeeds and is set so that, where control force per g is at a minimum, the autopilot cannot demand manœuvres reaching positive g structural limits or absolute negative g. It is possible to allow the autopilot to approach these levels by virtue of the monitoring system. When the autopilots change over automatically, the necessary mechanical actions will be initiated in sequence by the comparison monitor. The No 2 autopilot operates the starboard inboard elevator section and may be switched on and warmed up while not in use.

Control of the auto-flare manœuvre is considerably assisted by the fact that the gain of the Elliott autopilot is automatically reduced in proportion as the ILS localizer and glide-path beams become more sensitive near touchdown. An incidental safety factor is that the undercarriage is stressed to accept a vertical velocity of 10ft/sec which is approximately equivalent to an unflared touchdown along a 3° glide-slope.

It is necessary to provide a cockpit indicator by which the pilot can positively monitor the operation of the auto-flare sequence, but Vickers point out that although this instrument must be capable of indicating clearly the aircraft's situation, it should not be sufficiently pictorial to encourage the pilot to attempt to perform the flare-out manœuvre manually without automatic assistance. Monitoring of the automatic approach will be made



Layout of the VC10 split-surface elevator, tailplane controls and feel system, showing supplies and linkages and autopilot inputs

A VC10 cockpit layout proposed for BOAC. Each blind-flying panel includes flight system, combined a.s.i./angle-of-attack indicator, and altimeter, with the auto-flare indicator low on the right. Four h.p. compressor r.p.m. gauges are above the rectangular powered-control indicator panel and the autopilot controls are aft of the throttles. The co-pilot's trim levers are visible beyond the throttles. A Decca Flight Log is above the windscreen

possible by provision of a normal director instrument system based on the Bendix 100-series instruments. These will be supported by the normal flight instruments, a proportion of which will be servo-driven and derive their indications from an air data computer. A separate air data computer is to be provided for each autopilot; and each autopilot and comparison monitor will have its own pitot head and static port.

A minor, though intriguing, problem in the human aspect of auto-flare is the pilot's reaction to manual control of ailerons when the autopilot is controlling the elevators. Cross-coupling or unintentional overriding of the autopilot is unlikely to occur in the VC10 in this condition because of the considerable break-out force required to overpower autopilot control. The pilot can therefore treat the controls as he normally would in a fully manual landing without interfering with automatic pitch control. Vickers do not contemplate providing something like an automatic overshooting sequence as a stand-by in case of malfunction.

In order to ensure that no unforeseen difficulties occur in the control system, Boulton Paul are to carry out full rig-testing of the power control units themselves. Elliott will then rig-test the units in conjunction with the autopilot input and Vickers will finally incorporate the power control units and autopilots in a comprehensive full-scale test rig accurately reproducing the complete aircraft system.

VC10: Pt 3—Elliott Brothers

ALTHOUGH the company is a relative newcomer to the automatic landing field, both the flight control and radar divisions of Elliott Brothers (London) Ltd have a considerable background of achievement and the support of the Bendix organization, under licence from whom they manufacture radar, radio and the PB-20 autopilot system. It was on the strength of the licence for the last-named equipment that they were appointed to produce the duplicated autopilots for the Vickers VC10 and therefore also the auto-flare system which is being specified for that aircraft. There is close rivalry between Elliotts and their D.H.121 counterparts, Smiths, and an element of commercial security is therefore normally applied, but nevertheless some conclusions emerged from discussions with the company.

Firstly, Elliotts pointed out that the detailed operational research and exhaustive testing which resulted in the BLEU automatic landing system has put Britain well ahead in establishing the basic requirements of automatic landing, at least for the time being. The more elaborate American projects such as the Bell ALS and Gilfillan Regal provided a complex (and also very expensive) solution to a problem which, in its basic form, was already extremely difficult. Automatic landing for airline, as opposed to military use, was on the fringe of present techniques.

Because the VC10, as a long-range aircraft, should have autopilot control available throughout its flights, a duplicated system is an *a priori* requirement. For this purpose and for the more special auto-flare, Elliotts have considered a number of means of operating multi-channel systems and have settled on an arrangement of two separate autopilots each itself monitored by a comparator system. Only one of these operates at a time, the one being discarded in favour of the other in case of a fault. Such a changeover would be automatic in the case of auto-flare to afford a high survival probability of automatic control during the manœuvre. It must be possible to determine certainly when the 'driving' control system is malfunctioning; and it is obviously also necessary that the change-over from the one system to the other should be certain, immediate and effective.

In amplifying the desirability for maintaining automatic operation after a failure, Elliotts considered the problems faced by a pilot in taking over manually from an automatic system a matter of seconds before touchdown. A pilot must first assess the response of the aircraft to control movement before he can begin to fly it accurately. During a manual approach he tends to move the control column continually in an oscillatory fashion about a mean which he judges to give the desired control position. If he had to take over from the autopilot a few feet above the runway he would suddenly have to apply the visual scene to the control of his aircraft, establish the response to control column movement and then achieve a smooth touchdown, all in a matter of a few seconds—and this does not make allowance for correcting deviations.

There is no operational evidence that a pilot can accomplish such a manual recovery with a sufficient degree of reliability. The same problems apply to allowing the pilot to make a manual landing, following a failure of the automatic system, by reference to some pictorial indicator in the cockpit and without external visual references. There is a further complication in that the equipment required to produce such a pictorial indication may be unacceptably bulky and complex.

Auto-flare, the initial semi-automatic stage of landing, leaves the pilot to correct azimuth error which he is much better able to assess visually than glide-path and flare-out. As correction of azimuth error remains a manual operation auto-flare offers no very great prospect of the reduction in weather minima which can be achieved with fully automatic landing.

The provision of even auto-flare still raises a number of difficulties concerned particularly with the performance of ILS. With many present civil installations, it is difficult to use ILS glide-path signals at heights below about 150ft, and some attitude-memory or open-loop guidance stage appears to be necessary between the point at which glide-slope guidance must be released and the point when, over the runway, the radio altimeter can provide useful height signals for the flare-out. A radio altimeter appropriately designed can, and already does, provide sufficiently accurate height information up to 500ft, but it must have a reasonably level undershoot area from which to derive its signals. Unfortunately, this is all too often not available and almost anything from buildings or hills to sand dunes or ships may affect the usefulness of the surface as a reference. In the BLEU Autoland procedure the autopilot maintains control on an average pitch attitude reference for an appreciable time, and the effectiveness of such a method depends upon adequate starting conditions, autopilot characteristics and upon the absence of major disturbance during that time. It may, in fact, prove difficult to achieve satisfactory performance in this phase under civil operating conditions. Turbulence close to the ground and wind shear or gradient might throw the aircraft considerably off the approach path and may affect seriously the performance of the next positive guidance stage. A possible solution might be the use of a complete short-term inertial system designed to establish an inertial glide-path on which the aircraft can operate for the critical period when positive beam guidance might be lacking. With so short a working period, an inertial system would be relatively simple—"relatively" being the operative term because inertial equipment is inherently expensive.

During the flare-out phase, the radio altimeter signals will be used in such a way that the autopilot would recompute a flare-out path following a significant disturbance instead of attempting to regain the original path. For this stage Elliotts would use radio altimeters duplicated in conjunction with the autopilots.

For the broader and more complex automatic landing operation Elliotts appear to be by no means convinced that a system based on ICAO ILS will, in fact, be the best solution. A complicating factor is that if airborne equipment were to be multiplied to ensure uninterrupted automatic operation following a failure, then basically the ground equipment should be treated in the same way. Ideally the ground equipment should be supported by another system capable of providing the same information by a different means, but it is difficult to devise two different systems working on the same broad principle.

For low-level azimuth guidance there is the problem of providing Leader Cable over the undershoot area, where terrain and buildings might raise insuperable problems. One alternative studied by Elliotts is the provision of a high-frequency radio system called Leader Beacon designed to transmit parallel beams either side of the runway. The transmitting aerials would be placed beside the runway to cover the touchdown and a length of the approach equal to that of the present Leader Cable, i.e., about 5,000ft. Fault-monitoring, stabilized output and other accepted safety factors would be included.

Although problems were involved in providing actual Leader Cable for the approach, there is much to be said for laying these beside runways and taxiways to cover the landing run and subsequent taxying. In true zero-zero weather guidance would be needed right to the parking area.

Whichever of these methods is finally adopted for automatic landing, Elliotts consider that the duplicated monitored autopilot proposed for the VC10 will be suitable as the basic airborne system.

FLIGHT SYSTEM SURVEY...

PYE ILS AND AUTOMATIC LANDING

The new slotted aerial system for the Pye ILS glide-path installed near the seaward end of the new Hong Kong runway

*By B. Williams**

THE standard ICAO non-visual aid to final approach and landing is ILS; and this aid will be provided at all international airfields until at least 1970—and probably very much longer. Practically all airliners are fitted with ILS receivers and most modern types also have autopilot ILS couplers for automatic approaches. For these reasons, ILS will naturally be used, at least in the initial landing phase, in all automatic landing systems likely to become operational in the 1960s.

Until the advent of the latest Pye equipment, the extent to which ILS could be used for automatic landing was limited by the wide tolerances permitted in the localizer and glide-path by the present ICAO specification, which is framed to include systems, such as SCS51, developed during World War 2. The permissible variations in the course line of $\pm 0.3°$ will allow a lateral displacement of ± 55ft in the touchdown area of a modern instrument runway—about 10,000ft from the localizer aerials. This is about five times greater than that thought permissible for automatic landing. Again, the permissible variation in the glide angle of $\pm 0.1°$ will allow variations in height above a fixed reference point on the course line which are not acceptable for a direct changeover to an automatic flare-out system. Most glide-paths have used dipole aerials which are extremely difficult to adjust because of mutual impedances, with the result that glide-path angle is not correct or constant with distance along the path.

For these reasons, the RAE Autoland system used ILS for azimuth information only at distances greater than 4,500ft from touchdown and for elevation information down to heights on the glide-path greater than 150ft. Azimuth information down to touchdown is provided by Leader Cable laid on both sides of the runway to a distance of 5,000ft from touchdown. In most cases this takes it outside the airfield boundaries. Consequent problems in land purchase and technical maintenance at most civil airfields are nearly insoluble. The elevation information necessary for automatic flare-out is provided from a height of 60ft downwards by a radio altimeter; and the gap in positive guidance from 150ft to 60ft on the descent is covered by stored elevation information gathered from the glide-path in the preceding phase down to 150ft.

There is thus a very real need for improvement in ILS to allow it to be used with the existing British system, in azimuth down to touchdown if possible, so as to dispense with the Leader Cable system, (or at least down to 60ft so that Leader Cable may be confined within the aerodrome boundary) and in elevation down to the height of 60ft where the radio altimeter takes over.

The present Pye ILS provides these improvements. In azimuth, an aerial system consisting of two dipoles spaced symmetrically about the focus of a 70ft parabolic reflector provides a course line stable to better than 0.1° with only two electrical adjustments, one of carrier amplitude and the other of phase equality. The inherent stability of this simple aerial system is further increased by the addition of an automatic beam-control system which takes care of minor variations in carrier amplitude and modulation depth which may result from valve ageing. Long-term measurements at a monitor 500ft from the aerial have shown a course line stability of better than 0.06° with unattended equipment. Similar stabilities have been obtained with a monitor placed in the approach area short of the touchdown point. The very considerably improved performance of the present Pye localizer has been utilized in making more than 200 successful automatic landings without the aid of Leader Cables.

In elevation, the completely new glide-path aerial system using slot aerials, developed by Pye in conjunction with RAE, is free from mutual impedances inherent in the dipole type and, with simple adjustments, the glide-path angle may be very precisely set. Glide-path angle is maintained within very narrow limits at all heights from 20ft upwards on the course line. As with the localizer, minor aberrations are corrected by an automatic beam-control system. Precise glide-path information can now be supplied to an automatic landing system down to the height of 60ft at which radio altimeter control takes over. The possibility of providing an automatic flare-out from the glide-path system alone is being actively investigated.

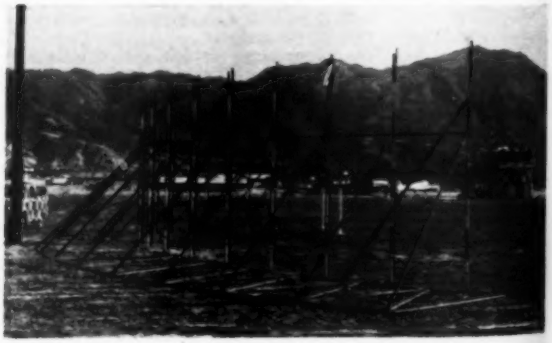
A decision to eliminate Leader Cable operation from the RAE automatic landing system has not yet been taken, mainly because of the possibility of interference with localizer information at low altitudes from localizer signals re-radiated from other aircraft flying in the vicinity. Such effects in fact have been observed, but precise information correlating them with aircraft tracks and heights is not yet available. The problem has been investigated theoretically by Pye and the maximum aberration of the course line between middle marker and touchdown has been deduced from the measured radiation patterns of the Pye localizer from aircraft of assumed echoing characteristics flying specific tracks in the localizer field. Experiments are now being conducted by Pye to determine practical values for aircraft flying these specific tracks. From these tests it should be possible to specify safe orbital radii and heights at which interference with automatic landings using Pye localizer alone would be negligible. If such orbits are operationally acceptable, there is no reason why Leader Cable should be necessary, except at those few places where the localizer cannot be properly sited on the runway centre-line.

The effect of illumination of other aircraft on the accuracy and stability of the glide-path has not yet been studied, because glide-path information has not hitherto been used below 150ft in the British automatic landing system. Investigation of possible effects may become necessary if the glide-path information is to be used below 150ft or if automatic flare-out using only glide-path information is seriously considered.

Future developments in the use of Pye ILS with an automatic landing system will be mainly directed towards perfecting the present system by reducing the time for changeover to the stand-by equipment in case of valve or other component failure during an approach. In this connection, the possibilities of continuous high-frequency switching are being investigated. Provision of continuous information to the controller on the precise instantaneous state of readiness of the ILS, from monitors in the approach area, is also being considered.

Pye feel that their present localizer aerial gives the minimum beam-width consistent with the accuracy and stability of the course-line necessary for automatic landing, and no major modifications are contemplated. Long-term development will be concentrated on the application of microwave techniques to the provision of the necessary information in azimuth and elevation for automatic landing.

The parabolic localizer aerial of the Pye ILS recently installed on the new runway at Hong Kong Airport. This system has been used in Britain for automatic landing without Leader Cable



*Adviser on Navigation Aids, Pye Telecommunications Ltd.

STANDARD TELEPHONES AND ILS

A HIGH-ACCURACY instrument landing equipment embodying novel features, such as a dual-beam localizer, a double-sideband mechanical modulation system and a transistorized monitoring chain, is now being produced by Standard Telephones & Cables Ltd. Localizer and glide-path operate respectively in the 107.9-111.9Mc/s and 328.6-335.4Mc/s bands, both employing 90 and 150c/s tone modulations, and the system is therefore compatible with existing ILS, but in most respects it surpasses ICAO requirements and represents the latest development in this field. It has been fully evaluated by the Ministry of Aviation and initial results are extremely encouraging. Orders have been received from MoA, the Belgian Régie des Voies Aériennes and Radio Suisse, while a number of others are being negotiated. Quantity production has begun.

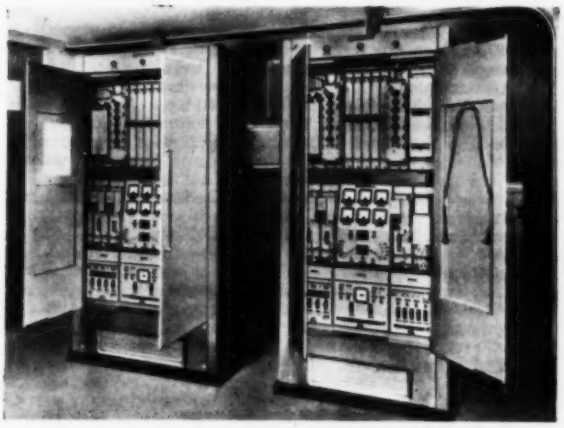
The dual-beam localizer has been adopted because the very narrow energy lobes radiated by the course (directional) array will eliminate or at least substantially reduce siting problems, while the superimposed radiation pattern of the subsidiary (clearance) array will provide correct indications outside the directional localizer sector and at the same time mask any secondary lobes radiated by the directional array.

Ideally, an aircraft approaching the touchdown end of the runway should receive only the 90 and 150c/s tones radiated directly from the localizer array, so that the pilot can fly accurately along the extended runway centre-line by keeping the ILS cross-pointer vertical needle centred. Unfortunately, most airports are surrounded by buildings and other obstructions so that in many instances the aircraft receives signals re-radiated from objects near the beam as well as direct signals. According to their phase, reflected signals will add to the direct signals and, by upsetting the equality of the tone modulations, cause the cross-pointer needle to deviate to left or right even though the aircraft is precisely over the extended centre-line of the runway. Re-radiations in fact cause course-bending.

As the aircraft approaches the runway, further complications arise because the path of the direct radiation decreases more rapidly than that of the reflected ray. Fluctuation of the cross-pointer needle is therefore aggravated, making the approach path extremely difficult to fly manually and totally unusable for auto-pilot-coupled approaches. The adverse effect of the reflected signals increases in direct proportion to the angle between the direct and reflected rays. If the reflecting objects are close to the centre-line (angle small) the phase-variation is slight and, as there is little difference in the relative paths, the resultant effect upon the cross-pointer at extreme range is small and causes only minor course changes as the aircraft nears the runway. If, on the other hand, the reflected object is some 500ft off the centre-line, phase-variation is considerable, the difference in path length between the direct and reflected signals is greater and course-bends occur which become progressively worse as the aircraft approaches touchdown.

Obviously, the width of the radiated beam must be narrowed so that, at the worst, only those objects near the centre-line will be illuminated. A narrow beam directed along the approach path is in any case unlikely to encounter more than very small structures which would not be illuminated sufficiently to cause trouble. Experience indicates that larger objects generally lie outside the 30° sector covering the centre-line.

These considerations have led S.T.C. to adopt a localizer aerial with both directional and all-round radiation patterns. At 12-14° either side of the course-line, the radiation is almost zero, while the peak level is at a maximum at about 2-3° off course. The ratio of on-course to off-course signals is such that reflecting objects more than about 8° off course are not illuminated sufficiently to give rise to any troublesome reflections, even if they are close to the localizer. Yet such a narrow-beam aerial gives rise to many minor lobes which, if not masked by the complementary clearance aerial radiation, would result in a number of false



Dual transmitters for Standard Telephones and Cables ILS

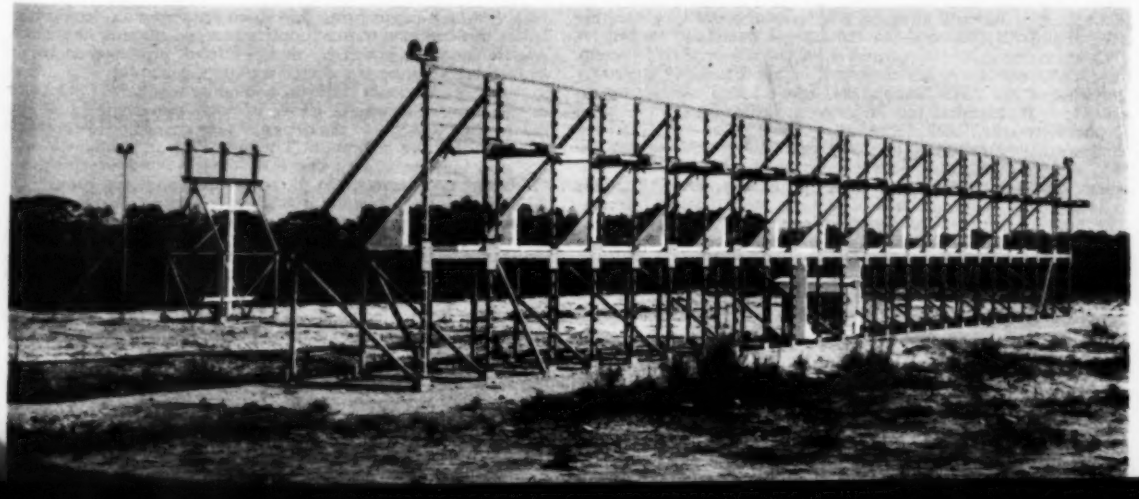
courses. The two aerials are energized by two identical transmitters whose frequencies are offset by about 9.5kc/s. On course, the ratio of directional to clearance aerial signals is approximately 3 : 1, while about 8° off course they become equal and outside this region the clearance signals predominate by a factor of about 3 : 1.

The band width of the airborne receiver exceeds the 9.5kc/s frequency difference between the two signals and it will therefore receive both, but the capture effect will result in the suppression of the weaker signal. In the region of the front (and back) course, therefore, reflections arising from the clearance radiations will be suppressed and exert no influence on the cross-pointer, while outside this area, radiation from the clearance antenna will predominate and cause a full-scale needle deflection in the appropriate direction.

The localizer directional aerial consists of a broadside array of 12 horizontal dipoles, backed by an open reflecter screen, which radiates an 18°-wide beam concentrated along the approach. The aerial system is carried on a metal framework about 85ft wide and 7ft high, as shown below. The clearance aerial is a broadside array of three horizontal dipoles mounted on a platform about 8ft high located some 50ft behind the main array.

Apart from the advantages of freedom from course bends and increased accuracy of azimuth guidance, a narrow beam coupled with the high-gain aerial greatly increases range and makes the system particularly suitable both for medium-range approaches

The localizer course array (right) and clearance array (left) of the S.T.C. ILS shown installed at Hurn Airport for MoA trials



FLIGHT SYSTEM SURVEY...

and for the very long runways associated with airports at high altitudes.

Another important S.T.C. innovation is the double-sideband mechanical modulator system, in which the amplitude-modulated carrier and sidebands-only outputs are produced by generating double sidebands in 90c/s and 150c/s balanced modulators. As well as simplifying adjustment of the modulation depth (a critical factor in the accuracy of the system) this method of modulation has other advantages. Variation of the relative phases of the 90c/s and 150c/s modulations is avoided by factory-determined positioning of the rotors on the motor shaft; the danger of course shift or distortion resulting from valve failure or ageing of electronic components is eliminated; signals are free from phase-modulation and cross-modulation is of a very low order; and reliability is substantially improved by virtue of reduced electronic complexity.

The electronic equipment is extremely compect, the directional and clearance transmitters being contained in a single cabinet which also includes all power supplies, mechanical modulator system, monitor receivers and the test meter, as shown on p. 245. Extensive use of transistors has allowed a reduction in the number of operating valves to eight.

As in all navigational systems, reliability is vital. The S.T.C. equipment includes a comprehensive fail-safe monitoring chain which automatically supervises all aspects of accuracy, operational performance and serviceability of the equipment. It consists basically of three field monitors for the localizer (two directional and one clearance) and two for the glide-path, all being electrically identical except for variations in aerial and input circuits to cater for different localizer and glide-path frequencies. The monitors are housed in double-skinned containers, the inner skins of which are hermetically sealed and designed for operation in any part of the world. The whole monitoring chain is completely transistorized, which, as well as avoiding the danger of failure or ageing of valves, drastically reduces space and power requirements.

These features, coupled with a high order of built-in reliability, provide a beam whose stability is of the order of 0.02°, representing an accuracy of 2ft at the touchdown end of a 2,000yd runway, and make any form of beam-correction system unnecessary. Beam stability and the facility of accurate beam-width adjustment allow the beam-width to be narrowed to, say, 3° (1.5° either side of the course line) or even less if required. The system is therefore eminently suited for use with an integrated flight system, and can provide a suitably stable course for automatic approaches. This very considerable improvement in course-line accuracy and stability, together with the siting advantages to be derived from the use of a very narrow front beam, make the S.T.C. localizer specially adapted for automatic approach application which demands the highest achievable accuracy in azimuth guidance.

The UHF glide-path equipment, which is basically similar in construction and layout to the localizer, may be adapted to provide an equi-signal, null or sideband reference glide-path as required. Hitherto, all ILS glide-paths have made use of the Earth's reflecting properties for their formation, so that terrain close to the aerial plays an important part in the accuracy of the radiated path. Unfortunately, the terrain is seldom perfect and most, if not all, glide-paths are subject to some distortion near the touchdown area. Considerable practical problems also arise if a glide-path angle of less than 2° is required. At a good site experience has shown that, despite these limitations, it is possible to fly the glide-path accurately down to a height of 20ft, but considerably more experience must be gained at a variety of sites before this performance can be more generally confirmed.

It is possible that an orthodox glide-path will not meet the requirements for automatic landing and for this reason S.T.C. are developing a scanning glide-path system which does not depend on ground reflections for its beam formation and will be capable of providing an accurate glide-path down to an angle of 1°.

The ILS ground element is completed by two or three marker beacons which form positive range marks for an aircraft approaching along the course line. They are identical in construction, but their individual modulation, keying rhythm and power output are pre-selected to suit their particular location.

All elements of the system are linked by normal telephone circuits to a remote control centre, usually located in the control tower, so that the airport authority can not only control the various transmitters and communicate with all sites of the system, but also see at a glance their serviceability state, and receive both visual and aural alarm should any defect develop.

In practice, the inherent reliability of the system is increased by the provision of duplicated transmitters and associated equipment which, in conjunction with fully automatic changeover equipment, limits time out of service—in the event of a defect—to a few seconds.

THE ARB AND AUTOMATIC LANDING

ANY auto-flare or automatic-landing equipment obviously involves safety considerations and the Air Registration Board must therefore be intimately concerned with the safety aspects of any such system proposed for commercial operation. For this purpose the ARB has since early last year been considering, in consultation with the corporations and the manufacturers, the airworthiness problems which might be raised by the auto-flare systems initially to be provided in the D.H.121 and the VC10.

The Board is closely following progress during the design stage. Its task in this instance is not straightforward, because several factors make it extremely difficult to see whether any regulations are needed and, if so, of what kind. No regulations have yet been stated, but it is expected that, when auto-flare reaches the operational stage, the ARB will already have an accurate idea of its characteristics and will have made an assessment of its airworthiness. This will also apply in the case of automatic landing.

Co-operation with the various agencies concerned at present takes the form of regular meetings, at approximately quarterly intervals, of the ARB landing and take-off aids committee, on which are represented the airframe manufacturers, the airline corporations—both their technical staff and pilots—BALPA, the equipment manufacturers, the RAE, the MoA (formerly both the MoS and MTCA), the Electronic Engineering Association, and others. By keeping directly in touch in this way, the ARB is able to decide in what specific areas it requires more detailed information, how much of the proposed systems might usefully be controlled by regulations and how far a particular system might have to be examined from the airworthiness point of view.

Yet the ARB is in a difficult situation in that it is most unwilling to inhibit new design by *a priori* regulations, especially in a project of this kind, when the safety requirements radically affect the basic design. A totally new development must be considered on its merits. In this instance the operators' specifications have necessarily made fairly close stipulations about reliability and safety and it may be that the ARB will be able to approve the systems on the strength of their compliance with the specification, without superimposing further conditions. Ideally, the Board would write regulations for no more than the degree of reliability to be attained, a condition which would affect the operator in producing the specification as much as the manufacturers in meeting it.

An example of the type of problem which the Board might have to consider is the effect of environmental conditions on the connecting elements of a multiple system. For instance, it could conceivably arise that a majority-vote system would break down if the majority of channels were together affected by environmental conditions, leaving a minority of correct signals to be overpowered. Factors which might bring this about are vibration, temperature, failure of a common source supplying several systems, humidity or contamination. Obviously, the multiplex principle should be applied as far through a servo loop as possible, but it is difficult to decide whether this must be defined by regulation. Safeguards in the form of airworthiness regulations have in the past been much easier to apply to the design of new aircraft or to equipment added to existing airframes. The auto-flare and automatic-landing case is quite new in that it involves a far greater degree of "freezing" or integration at the outset than anything before. The ARB, therefore, is keeping itself fully informed, making sure that it has the necessary information to assess these new systems while maintaining a balance of impartiality between the two rival groups which are each working out their own solutions. As an overall aim it has been stated that a fatal accident risk not greater than 1×10^{-7} flights might be the target in reliability, with the intention of providing for a factor of 1×10^{-8} if possible. For the moment, ARB is not stating more specific requirements.

INERTIAL NAVIGATION 1960

By R. P. G. Collinson, BSc(Eng), AMIEE*

INERTIAL navigation is an absolute system which will supply information on the velocity and present position of a vehicle, and also on its attitude, from fundamental information measured by the inertial equipment itself.

The basic principles are simple, but the individual components must be extremely accurate. It is in fact the accuracy required from gyroscopes and accelerometers, and the need for precision in computing operations such as integration and differentiation with respect to time, multiplication, division and the derivation of trigonometrical functions, which delayed for so long the development of practical systems. But reliable and accurate inertial systems are now available. The cost has been fantastic but has been justified by the military requirement, and development has been relatively rapid on this account. Although cost is still a major deterrent to civil application, the equipment is available and its installation in civil aircraft can be regarded as only a matter of time. Some civil applications are mentioned later in this review.

The US Navy atomic submarines *Nautilus* and *Skate* have demonstrated the practicability of inertial navigation at sea. It can be presumed that surface warships and eventually even merchant ships will also be fitted with such systems.

The fundamental principle of inertial navigation is to measure the components of a vehicle's acceleration with respect to a known set of axes. Provided the initial conditions are known, the component velocities can be obtained by integrating these accelerations with respect to time; and the distance travelled along each axis can then be measured by a further process of integrating the velocity components, as shown schematically in Fig 1.

Acceleration information is the starting-point, because it is the one kinematic quantity which can be measured within the vehicle. Acceleration is derived through Newton's laws of dynamics by measuring the force required to maintain a suspended mass in alignment with the vehicle so that it has the same acceleration.

A vehicle moving in three dimensions, such as an aircraft or missile, has six degrees of freedom; so an inertial system must measure acceleration either along a known set of axes with three accelerometers mounted on a stable platform defining the three axes, or alternatively with six accelerometers mounted directly on the vehicle. The latter arrangement is sometimes called a strapped-down inertial system. The former is most commonly used and appears to be superior at the moment, although the strapped-down system should be cheaper because it dispenses with the gyro-stabilized platform, though it requires a more complicated and very accurate computing system. Most of the information on strapped-down systems is classified as secret and this article will therefore deal with systems using a gyro-stabilized platform. Without infringing security (which also applies to stable platform inertial systems), it is possible to consider general principles and to assess inherent errors and the accuracy required from basic components.

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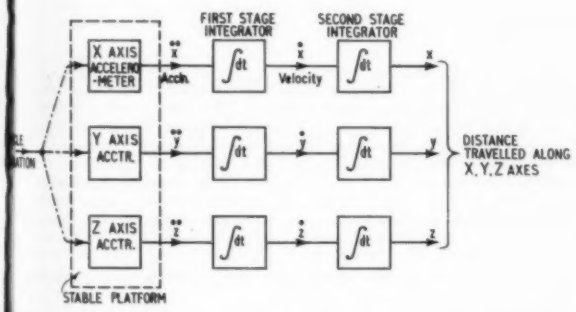
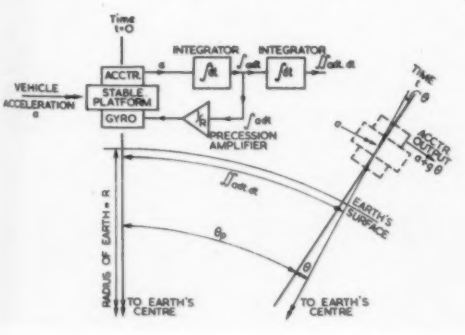


Fig 1. Measuring and computation in a basic inertial navigation system

Fig 2. Basic 84-minute pendulum, or Schuler-tuned inertial system



The Schuler or 84-minute Pendulum

All practical inertial systems for navigating with respect to the Earth have an inherent 84-minute period oscillation mode. It is essential to understand this characteristic, although the proviso should be made that it will have little effect in reducing errors if flight-time is only a matter of minutes.

The 84-minute pendulum characteristic, first defined by Schuler and named after him, makes the system behave as if the accelerometers on the platform were continually oscillating about the Earth's local vertical with an 84-minute period. Schuler pointed out that the bob-weight of a simple pendulum with a length equal to the radius of the Earth would stay at rest at the Earth's centre, thus defining the local vertical, irrespective of any movement of the point of suspension over the Earth's surface. A basic inertial system which will oscillate about the local vertical with an 84-minute period to make a practical form of Schuler's Earth radius pendulum or Schuler tuning, is shown in Fig 2.

A current fed into the gyro torque motor from the precession amplifier will cause the gyro and platform to precess at a rate proportional to this current. The rate of rotation is equal to $(\frac{I}{R} \times$ first integrator output), where R is equal to the radius of the Earth. If the platform is initially vertical, first integrator output $= \int a\,dt$, where a = vehicle acceleration.

The rate of rotation of the platform is $\dot{\theta}_p = \frac{I}{R}\int a\,dt$

Thus angle platform rotates in space $\theta_p = \frac{I}{R}\iint a\,dt\,dt$

However, $(\iint a\,dt\,dt)$ is the distance travelled over the surface of the Earth in time t, and $(\frac{I}{R}\iint a\,dt\,dt)$ is therefore the angle through which the vehicle has rotated round the Earth. The platform is thus rotated to stay aligned with the Earth's local vertical irrespective of the vehicle's speed or acceleration, if there are no sources of error present.

Consider now the effect of an initial tilt θ_0 from the vertical. (The effect of a bias in the accelerometer is also equivalent to an initial tilt.) Let θ = tilt of the platform from the local vertical, at any instant. Acceleration measured by the accelerometer = $(a+g\theta)$, if θ is small.

The equation of motion of the system is

$$\dot{\theta}_p = \frac{I}{R}\int (a+g\theta)\,dt$$

$$\text{i.e. } \ddot{\theta}_p = \frac{a}{R} + \frac{g}{R}\theta$$

Now, angular acceleration of the local vertical $= \frac{\ddot{a}}{R} = \ddot{\theta}_p + \ddot{\theta}$

Substitution yields $\ddot{\theta} + \frac{g}{R}\theta = 0$. The solution of this equation

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for the initial conditions $\theta(0)=\theta_0$; $\dot{\theta}(0)=0$ is

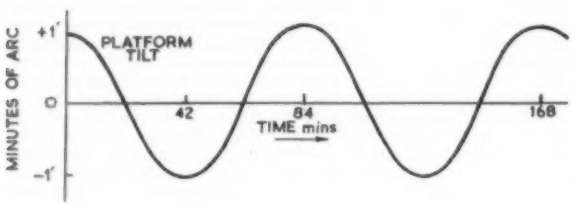
$$\theta=\theta_0\cos\omega_0 t, \text{ where } \omega_0=\sqrt{\frac{g}{R}}$$

The platform thus oscillates about the local vertical with amplitude θ_0, and period $\frac{2\pi}{\sqrt{\frac{g}{R}}}$ that is, 84 minutes.

$$\text{Distance error}=\iint g\theta_0\cos\omega_0 t\,dt\,dt$$

$$=\frac{g}{\omega_0^2}(1-\cos\omega_0 t)$$

as the initial conditions are zero. Thus a tilt of 1min of arc will cause an oscillatory error between zero and 1 nautical mile (see Fig 3a).



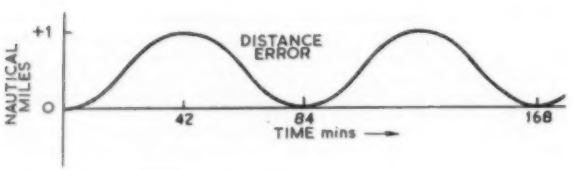


Fig 3a, above, shows errors caused by an initial tilt of one minute of arc. Fig 3b, at right, shows errors caused by a constant gyro drift of 0.1°/hr. The first are oscillatory, the second divergent

Now, consider the effect of the platform being initially vertical but with a gyro drift causing the platform to rotate at a constant rate W

$$\dot{\theta}_p=\frac{I}{R}\int(a+g\theta)dt+W$$

A similar process, substituting the initial conditions $\theta(0)=0$; $\dot{\theta}(0)=W$, gives

$$\theta=\frac{W}{\omega_0}\sin\omega_0 t$$

The platform thus oscillates about the vertical as before with an 84-minute period. A wander rate of 0.1°/hr gives sinusoidal oscillations with an amplitude of only 1.4min of arc.

$$\text{The distance error}=\iint\frac{gW}{\omega_0}\sin\omega_0 t\,dt\,dt$$

$$=WR\left(t-\frac{1}{\omega_0}\sin\omega_0 t\right)$$

as the initial conditions are zero.

The distance error is thus proportional to the time of flight, the oscillatory component being swamped after a while. A gyro drift of 0.1°/hr will give an error of 8.4 nautical miles after 84 minutes—an indication of the critical importance of gyro drift and flight time.

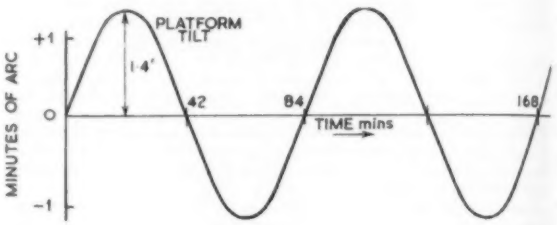
For short flight times, of the order of five minutes,

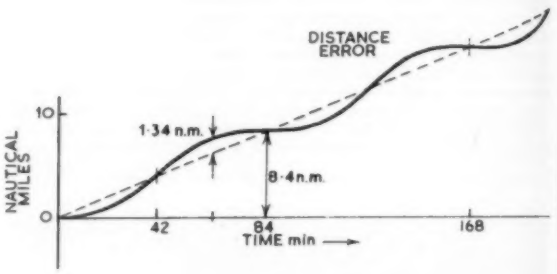
$$\sin\omega_0 t\simeq\omega_0 t-\frac{(\omega_0 t)^3}{6}$$

with the result that distance error $\simeq\frac{1}{6}g\,Wt^3$

The error caused by gyro drift is thus proportional to the cube of time for short flights. The graphs in Fig 3(b) show the errors with a constant gyro drift. In practice, this is not a constant quantity and the distance error over a long period is proportional to the square root of the time of flight if the variation is random.

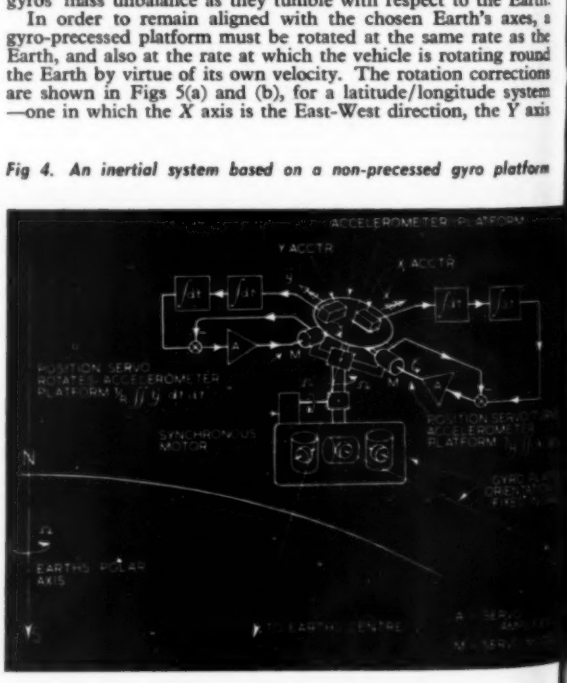
The gyro torque motors must have high linearity to give accurate precession. An alternative system to overcome this limitation is to allow the gyro platform to maintain its orientation in space and to rotate a separate platform on which the accelerometers are mounted, as in Fig 4. The gyro platform remains fixed in inertial space so that its gyros tumble with respect to the Earth's surface as the vehicle moves round the Earth. A drive shaft running parallel with the polar axis coupling the gyro platform to the accelerometer platform is rotated at Earth's rate to maintain the accelerometers aligned with the Earth's axes. Additional gimbals allow the platform to be aligned with the Earth's local vertical by the 84-minute pendulum feedback loop. Vehicle position is obtained at any instant by direct measurement of the angles through which the accelerometer platform has been driven from its initial position, using the gyro platform as a reference. The disadvantages of this system are greater size, weight and complexity (because of the number of gimbals required) and gyro drift caused by the changing effect of the gravity vector on the gyros' mass unbalance as they tumble with respect to the Earth.





In order to remain aligned with the chosen Earth's axes, a gyro-precessed platform must be rotated at the same rate as the Earth, and also at the rate at which the vehicle is rotating round the Earth by virtue of its own velocity. The rotation corrections are shown in Figs 5(a) and (b), for a latitude/longitude system —one in which the X axis is the East-West direction, the Y axis

Fig 4. An inertial system based on a non-precessed gyro platform



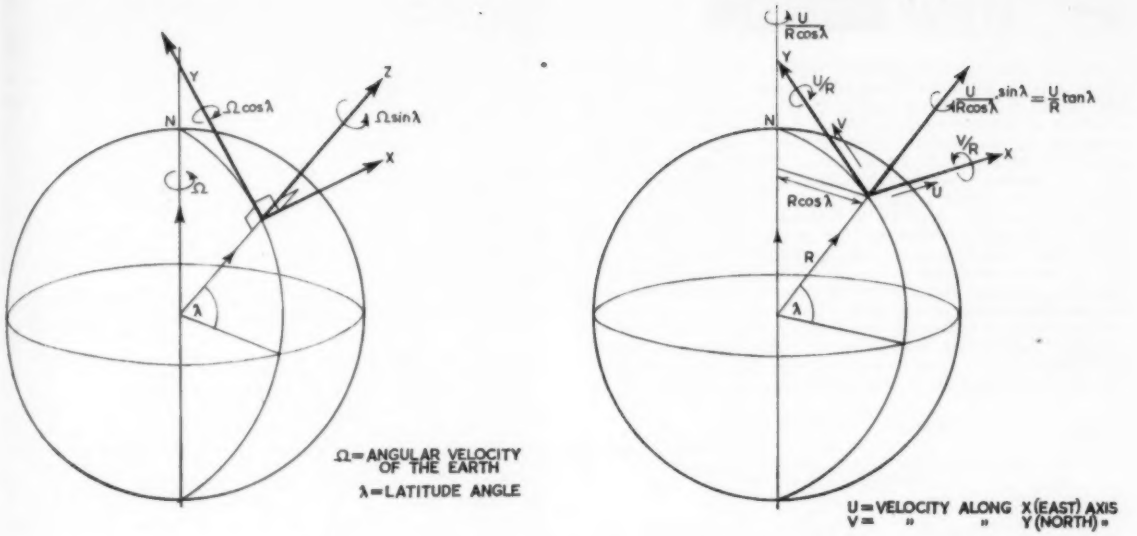


Fig 5a at left and Fig 5b at right show respectively the corrections to be applied for the Earth's rotation and the vehicle's rotation terms

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the North-South direction and the Z axis the local vertical. The correction terms may also be tabulated as follows:—

Correction Term	X-axis	Y-axis	Z-axis
Earth's rate... ...		$\Omega\cos\lambda$	$\Omega\sin\lambda$
Vehicle's rate ...	V/R	U/R	$U/R.\tan\lambda$

Where U=East velocity, V=North velocity, Ω=angular rate of rotation of the Earth, λ=Latitude angle.

The precession for $\frac{U}{R}$ and $\frac{V}{R}$ forms the 84-minute pendulum feedback loop. The azimuth gyro must be precessed at $(\frac{U}{R}\tan\lambda)$ and this term becomes infinite at the poles when $\lambda=90°$ so that the system is restricted to latitudes below 80° north and south of the equator. Other co-ordinate systems can be adopted to overcome this limitation, but they entail a more complicated computing system, usually calling for digital computation to meet the required accuracy.

Because the platform is being rotated in space to stay aligned with the Earth's local vertical, the accelerometers will also measure both Coriolis and centrifugal accelerations. These must be compensated for and the major corrections are:—

Acceleration Correction	X-axis	Y-axis	Z-axis
Coriolis Acceleration	$-2V\Omega\sin\lambda$	$2U\Omega\sin\lambda$	$-2U\Omega\cos\lambda$
Centrifugal Acceleration	$-\frac{V.U}{R}\tan\lambda$	$\frac{U^2}{R}\tan\lambda$	$\frac{U^2+V^2}{R}$
Gravity			$g_o\frac{R^2}{(R+h)^2}$

where h=height above the Earth's surface. Still further correction must be applied to allow for the fact that the Earth is an ellipsoid and not a perfect sphere.

Determining height inertially is limited by flight time because the error builds up exponentially with time. Gravity varies with altitude according to the inverse square law so that gravitational acceleration at any height $h=g_o\frac{R^2}{(R+h)^2}$

where g_o = gravitational acceleration at the Earth's surface. Gravitational acceleration must be backed off and errors in correcting for its variation cause this exponential build-up with time. Accuracy for a short period is good, but monitoring is required for long-period operation and can be obtained either barometrically or from a radio altimeter.

The problem of inertially navigating aircraft or missiles having gyro drift and other errors which will give an unacceptable overall error on pure inertial information is solved by monitoring the inertially computed velocity or position with velocity as measured by Doppler or fixes obtained by radio and radar. The platform can alternatively be made to track a fixed star. Such a stellar/inertial system is used in the SM-62 Snark intercontinental cruise missile and has achieved very high accuracy.

The overall accuracy of a Doppler-monitored inertial system is high because the inertial data will fill in the information lost in smoothing out the Doppler noise. If the Doppler is inoperative, the system will also give accurate information on inertial data alone for a period depending on gyro drift. Such monitoring can be used also to damp out the 84-minute oscillation characteristic of the inertial system if this becomes excited.

An error arising when the horizontal accelerometers are not aligned on their correct axes, because of an initial azimuth error or azimuth gyro drift, can be corrected by a computer which works out the azimuth error from the last fix, present fix and dead-reckoning position, the fixes being obtained from astro sights, radio or radar.

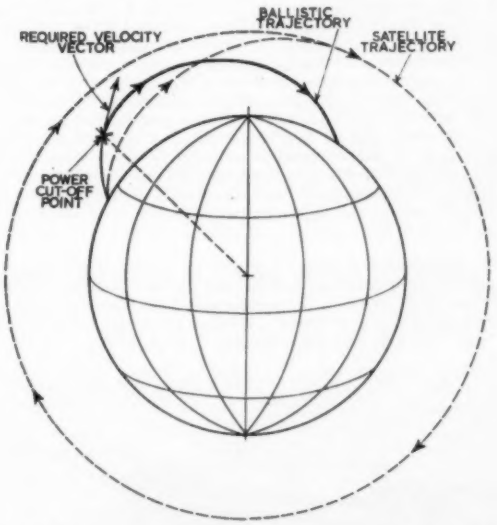

Fig 6. Ballistic and satellite trajectories. A specific velocity vector would be required for the satellite vehicle as it is for the ballistic missile

In guiding an ICBM or launching a space satellite, the basic problem is to acquire a certain velocity vector at a given point in

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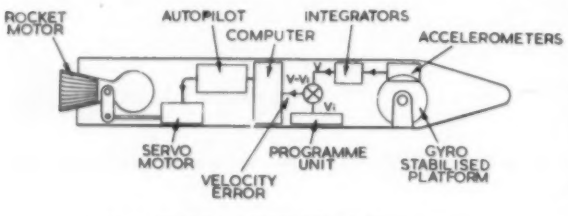
space after which the rocket power will be cut off and the missile left to follow a ballistic trajectory to its target, or alternatively go into orbit. As illustrated in Fig 6, this velocity vector is the resultant of three component velocities which are continuously measured by the inertial equipment and compared with pre-computed values. The velocity errors are fed into a computer which calculates the action to be taken by the autopilot in controlling the rocket motor to bring the errors to zero (see Fig 7). In this case it is only necessary to compute velocity and only one stage of integration is needed. The guided time of flight is only of the order of three minutes and the critical factors are gyro drift due to mass unbalance because of the high accelerations and vibration, and scale factor errors in the accelerometers because of the very high velocities acquired.

Atlas has been quoted as having an accuracy of two miles over a range of 5,000 miles. If the power cut-off velocity is of the order of 20,000ft/sec, the error in acquiring this velocity cannot exceed 8ft/sec, which gives some idea of the accuracy required. In fact,



V = MISSILE VELOCITY COMPONENT

Vi = REQUIRED MISSILE VELOCITY COMPONENT

Fig 7. Simplified diagram of the inertial guidance components in a ballistic missile

there are additional sources of error, such as dispersion of the nose cone, and the velocity error at power cut-off must in practice be appreciably less than 8ft/sec.

Inertial Components

As already stated, accuracy is essential in inertial components and particularly in gyros. The stable platform which they control is suspended in a set of gimbal rings giving it at least three degrees of freedom, so that it can maintain a given angular orientation irrespective of vehicle attitude. Any tendency for the platform to rotate with respect to inertial space must be detected and the gyro is the most suitable instrument for this purpose because its sensitivity to a change in angular position is dependent upon its angular momentum—that is, the product of its moment of inertia and angular velocity about its spin axis and not just its moment of inertia as with, say, an accelerometer. For a wheel running at 24,000 r.p.m. (2,500 rads/sec) this corresponds to a factor of 2,500.

Three single-axis gyros or, alternatively, two 2-axis gyros can be used for stabilizing a platform in space and deviation of the platform from its orientation in space is caused by extraneous torques acting about the gyro gimbal axes. Two main types of gyro with virtually frictionless gimbal bearings have been developed to a state where their drift is no longer dependent on gimbal bearing friction, as it is with conventional gyros. One is the air- or gas-bearing type in which the gyro is supported by a layer of air between the gimbal and its case, as in Fig 8. Gyros of this type were being developed by the Germans for the V-2 rocket at the end of World War 2 and development has been continued at the US Army's Redstone Arsenal by the German scientists transferred there after the war. The team at Redstone has succeeded in producing extremely high-performance air-bearing gyros and these are used in the Jupiter IRBM which has achieved high accuracy and reliability. Many German scientists were also transferred to the Soviet Union after the war and the Russians may have developed air-bearing gyros for their inertial guidance systems, but this is mere speculation.

The other type is the liquid flotation gyro in which a container housing the rotating assembly floats in a dense fluid (Fig 9). A condition of neutral buoyancy is achieved which will be unaffected by any acceleration applied to the gyro. Jewel bearings locate the gimbal axis, but friction is extremely low because the bearings are unloaded. The density of the fluid must be kept constant in order to maintain flotation and fluid temperature is therefore controlled by a thermostat in the gyro case. Temperature outside the case must remain within a small range if the fluid-temperature thermostat is to operate, and a cooling system is usually required to control ambient temperature within the platform container. But the coolant flow must not produce temperature gradients across the gyro which, by causing convection currents in the fluid, might give rise to spurious torques.

The radial clearance between float and case is usually very small, so that the viscous damping is very high. Thus, if the gyro is rotated about its input axis, it will precess about its output axis at a rate such that the viscous torque developed about the output axis is equal to the precession torque required to cause rotation about the input axis. Rate of rotation about the output axis is therefore proportional to the rate of rotation about the input axis, so that the change in output angle will be proportional to the change in input angle. Because of the proportionality between output and input angular movement, this type is known as an integrating rate gyro. The ratio of output to input angular rotation varies between 1:1 and 6:1 for most liquid flotation gyros.

Negligible viscous damping is exerted about the output axis in an air-bearing gyro and this gives it appreciably different characteristics from integrating rate gyros. The gyro output angle is in fact equal to the integral of the input angle with respect to time.

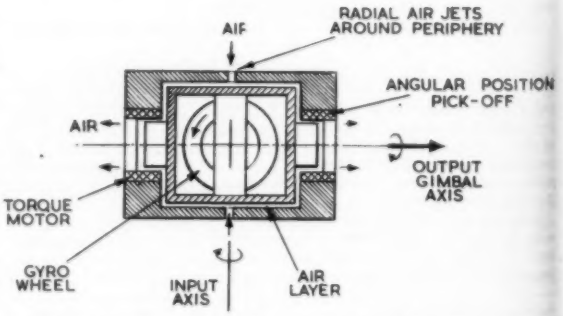


Fig 8. General arrangement of an air- or gas-bearing, single-axis gyro. This is an alternative to liquid flotation, shown in Fig 9

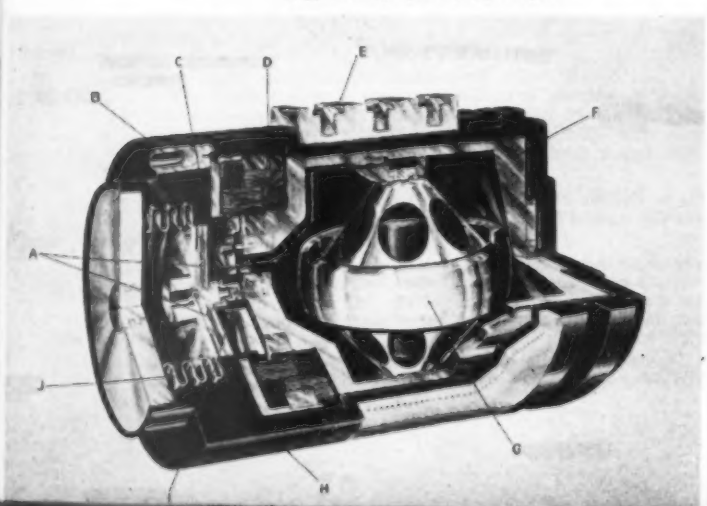


Fig 9. Minneapolis-Honeywell floated miniature integrating gyro. The flotation liquid is contained between outer gimbal and case. A, baffle-plate heater; B, terminal; C, flexible lead; D, Dualsyn combined pick-off and torque motor; E, heater and sensing element; F, outer gimbal; G, gyro rotor; H, case; I, pivot jewel

Gyro drift results mainly from acceleration acting on mass unbalance of the floating part following dimensional changes and non-isoelastic deformation of the spin-axis bearing. Mass unbalance caused by a shift of the mass centre of only 40×10^{-4} in under normal 1g conditions can cause a gyro drift of the order of 1°/hr, so that dimensional stability in flight is critical. Non-isoelastic spin-axis bearing systems have unequal stiffness axially and radially so that the mass centre will deflect both along and normal to an acceleration vector, producing an unbalance moment. Under vibratory acceleration the vibration is rectified and a uni-directional torque is produced, with resultant gyro drift. Drifts caused by non-isoelastic deformation are proportional to the square of the acceleration.

Space stabilization with a single-axis gyro is shown schematically in Fig 10. The servo motor torque is arranged to be proportional to the gyro output signal which is suitably phase-advanced in the amplifier to compensate for lags in the servo loop. A disturbing torque acting about the gyro input axis, such as the friction torque developed in the platform gimbal bearings when the vehicle

attitude changes, causes the gyro to rotate about its output axis until the resulting servo motor torque is equal and opposite to the disturbing torque. Amplifier gain is high so that the gyro output angle is very small and the platform moves a negligible amount. Considerable stabilizing torque is obtained from the gyro if it has a high angular momentum and this, coupled with platform inertia, supplies the necessary stabilization to high-frequency disturbances which the servo cannot follow. The gyro has an electrical torque motor to apply a torque about the output gimbal so that it can be precessed to any required position.

With a platform stabilized by two-axis gyros, the gyros are completely free to maintain a given orientation in space, and pick-offs are mounted on each gyro gimbal axis to measure the angular movement of the spin axis relative to the case. Servo motors on the platform gimbals drive the platform to follow-up the gyro gimbals, the gyro pick-off supplying the servo error signal. The platform gimbal servos are thus essentially position follow-up servos. Two-axis gyros are used in the S. G. Brown Master Reference Gyros and have been used in the American Bosch Arma ICBM inertial system.

Stabilization of a platform having three degrees of freedom (azimuth, pitch and roll) is complicated by the fact that, in order to maintain the correct sense of feedback, when the azimuth angle varies more than 360°, it is necessary to resolve the signals from the X and Y gyros before feeding them to the pitch and roll servos.

Two basic configurations are commonly used for a three-axis platform. In the first, the platform is suspended inside the pitch and roll gimbals, giving full freedom about the roll axis but, because of gimbal lock, only about ±60° about the pitch axis. When the pitch angle is not zero, both the pitch and roll gimbals must be accelerated by the roll servo motor at (tan θ)×(yaw angular acceleration), where θ is the pitch angle. The acceleration becomes infinite where $\theta=90°$ and the platform would therefore topple. The roll gimbal, being outermost, also has considerable inertia so that the roll motor must supply large inertia torques when the gimbals are not orthogonal. Published photographs show the Thor platform to be of this type. Gimbal lock limitations may be removed by providing a fourth degree of freedom so that three axes can always remain roughly orthogonal; and a four-gimbal platform is therefore necessary for aircraft which have to be capable of flying inverted. The Sperry platform for the North American X-15 is of this type.

An alternative configuration for a vehicle which requires only limited freedom about three axes is the so-called "inside-out" or "knuckle joint" platform illustrated in Fig 11. This has three

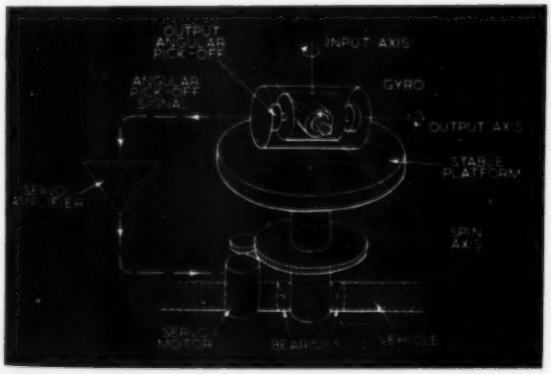


Fig 10. Single-axis space stabilization servo

main advantages: (1) The roll and pitch gimbal inertias are very small so that the torque requirements for the roll motor are much smaller than those for the centrally suspended type; (2) The components, such as gyros and accelerometers, are very accessible; and (3) The platform inertia is high and this assists platform stabilization for high-frequency torque disturbances.

Its limits of angular freedom will, however, be lower than those of the centrally suspended type, because of its geometry. The "inside-out" type of platform is used in the ballistic missiles developed by the US Army Redstone Arsenal, such as Jupiter and its satellite-launching derivatives.

Both direct drive and gear drive servo motors are used. The former have the advantage that their inertia does not have to be accelerated when the vehicle attitude changes and there is no backlash, but their power requirement is generally higher than that of a geared motor and they are usually larger and heavier. Nevertheless, the torque required to accelerate a geared servo motor through its gearing is small if the gear ratio is low. Both types have their pros and cons.

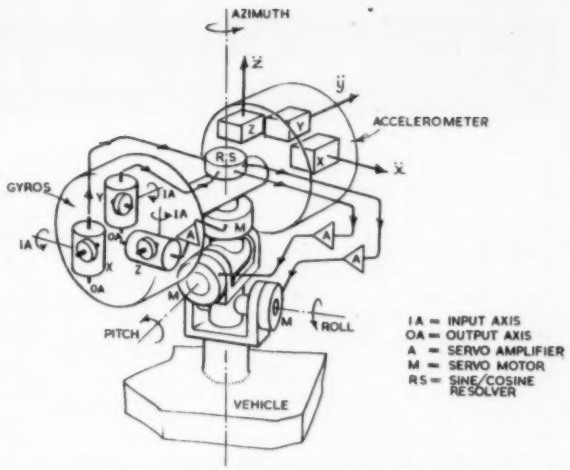


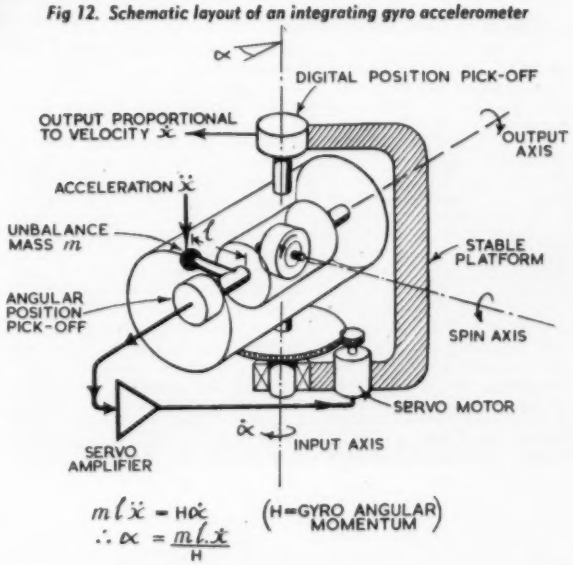
Fig 11. Schematic representation of an "inside-out" or "knuckle joint" three-axis stable platform

Two main types of accelerometers are in use. In the first, the deflection under acceleration of a beam with known unbalance mass is sensed by a pick-off, amplified and fed to a force motor which exerts a force to null the deflection. The force exerted is equal to the product of unbalance mass and the acceleration. Because the force motor applies a force proportional to the current through it, the acceleration may be obtained by measuring this current. Accuracy is determined by the stability and linearity of the force motor and by the bias forces in the suspension.

The second type of accelerometer, which is inherently more accurate and has the advantage that it will perform the first integration as well, is known as the integrating gyro accelerometer and is shown schematically in Fig 12. The gyro has a known unbalance about its output gimbal axis so that an acceleration acting parallel to the input axis will produce a torque proportional to this acceleration about the gyro output axis. The gyro moves a small amount about the output axis and produces a signal from the output pick-off which, when amplified, causes the servo motor to rotate the gyro about its input axis at a rate such that the precession torque created exactly balances the unbalance torque caused by the acceleration. The pick-off then returns to its near null position. The rate of rotation about the input axis is thus proportional to the acceleration, so that the input angle will be proportional to the time integral of the acceleration, that is the velocity. A digital pick-off can be mounted on the input shaft so that a digital output proportional to vehicle velocity is obtained. The stability of the backing-off torque is dependent on the stability of the gyro angular momentum and this can be made very high.

For computations, both analogue and digital techniques are used in inertial systems. With an analogue system, integration can be performed by an electronic feedback d.c. amplifier of the Miller type or an electro-mechanical integrator such as a velodyne. Multiplication and division can be performed with a position servo or an all-electronic multiplier. Trigonometric functions can

Fig 12. Schematic layout of an integrating gyro accelerometer



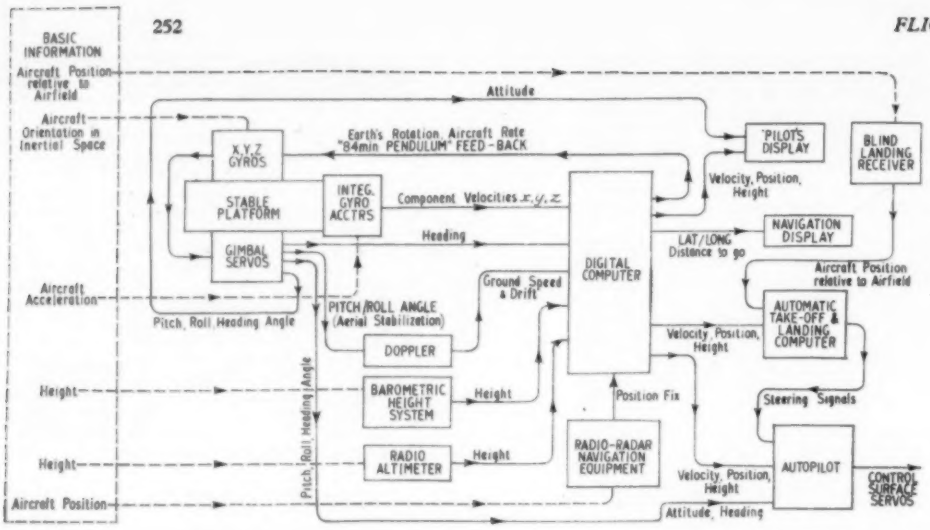


Fig 13. Proposed integrated inertial system for a commercial airliner for navigation, flight control, instrumentation and automatic landing and take-off

FLIGHT SYSTEM SURVEY...

be generated using sine/cosine resolvers, either of the mechanical type or specially wound potentiometers, or synchro resolvers. Most instruments produce analogue outputs so that the coupling between the analogue computer and the inertial components such as gyros and accelerometers is simple—the gyro torque motors, for instance, require an analogue input in the form of a current. Analogue computing elements can be given a speed of response much higher than that of the physical system so that computation can be carried out in real time. Nevertheless, expensive precision components must be used and it is difficult to obtain an overall accuracy in a computing chain better than 1 part in 1,000. Accuracy of individual elements must be of the order of 1 in 10,000.

With a digital computing system, only the size of the computer limits the accuracy which may be achieved, but analogue-to-digital converters are usually required to couple the computer to the inertial instruments. If much serial computation is involved it may also be difficult to keep the problem in real time. Information emerges from a digital computer at discrete intervals and the stability of the control loop may therefore be affected by time lags. In spite of these difficulties, most new inertial systems use digital computing techniques, but a certain number of analogue operations will always remain to be carried out.

Cryogenic Gyros. Since this article was written the first official details have been released of work by General Electric, Jet Propulsion Laboratory and Minneapolis-Honeywell on cryogenic and electrostatic gyros, both employing extreme-low-temperature and super-conductivity principles. Niobium metal is being used, together with liquid helium, at about 4°C above absolute zero. Wander-rates a factor of ten less than present values are predicted, and many other applications for the technique are forecast.—Ed.

Prospects of Civil Applications

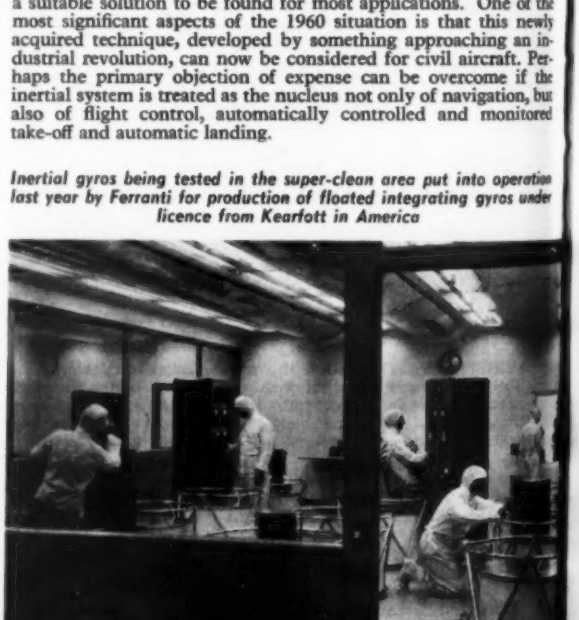
The first application of inertial equipment to civil aircraft will probably be the use of an inertial gyro for heading reference in a civil Doppler navigator. A heading gyro with a drift of 0.1°/hr would allow the inherent accuracy of the Doppler element to be exploited.

For a supersonic airliner, it is obvious that navigation must be automatic because of the speeds involved; but an automatic navigation system entirely dependent on ground-based aids would be inadequate because of incomplete coverage and the critical effect of any failure. If an inertial gyro is thought necessary for a Doppler navigator, it would be logical to go a step further and provide for a full inertial system and use Doppler as a monitor. With an inertial heading gyro the correction terms for the aircraft's velocity of rotation round the earth must be so accurate that it is simpler to derive complete information inertially and monitor it with Doppler. The advantages of a full inertial system are that, firstly, positional accuracy is better than that of Doppler alone because the inertial data will fill in the information lost in smoothing Doppler noise. Secondly, inertial information will remain reasonably accurate in the event of a Doppler failure. With a constant gyro drift of 0.05°/hr the error after one hour would only be 3 n.m., without any Doppler monitoring. Thirdly, very accurate attitude and directional reference and velocity and positional information are available directly to the autopilot. Further advantages are that, for the gyro drift quoted, vertical reference accurate to ±0.7min of arc is available for an automatic astro sight which can supplement the navigation system. Finally, the inertial velocity and position information is available for use in automatic landing and take-off systems.

A possible future civil inertial system, integrated with the autopilot for both normal flight and automatic landing and take-off is illustrated in Fig 13. In this system, the gyros are precessed because this results in a simpler, smaller and lighter platform. Either floated integrating rate gyros or the air-bearing type may be used, but the system should be based on hardware already available. Integrating gyro accelerometers are recommended because of their accuracy and because they can give a digital output proportional to velocity, thus simplifying computation. A digital computer would be necessary to obtain the required accuracy; and suitable units of this type should be available "off the shelf" in the next year or so. The co-ordinate system may also be varied to avoid having to precess the gyros for over-the-Pole flights. Barometric and radio altimeter information would be used to monitor the inertial height data.

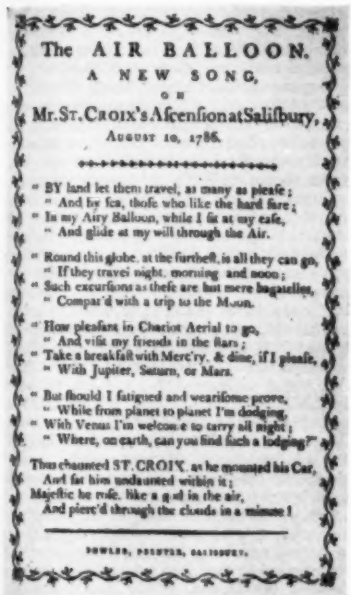
The problems, then, are considerable, but enough is known and a sufficient variety of methods and components is available to allow a suitable solution to be found for most applications. One of the most significant aspects of the 1960 situation is that this newly acquired technique, developed by something approaching an industrial revolution, can now be considered for civil aircraft. Perhaps the primary objection of expense can be overcome if the inertial system is treated as the nucleus not only of navigation, but also of flight control, automatically controlled and monitored take-off and automatic landing.

Inertial gyros being tested in the super-clean area put into operation last year by Ferranti for production of floated integrating gyros under licence from Kearfott in America



Straight and Level

THE song below is the second that this column has had the pleasure —ladies and gentlemen—of introducing. (The earlier one was a waltz dedicated to Colonel Cody.)



The AIR BALLOON.

A NEW SONG,

ON

Mr. ST. CROIX's Aſcenſion at Saliſbury,

AUGUST 10, 1786.

" BY land let them travel, as many as pleaſe;
" And by ſea, thoſe who like the hard fare;
" In my Airy Balloon, while I ſit at my eaſe,
" And glide at my will through the Air.

" Round this globe, at the furtheſt, is all they can go,
" If they travel night, morning and noon;
" Such excurſions as theſe are but mere bagatelles,
" Compar'd with a trip to the Moon.

" How pleaſant in Chariot Aerial to go,
" And viſit my friends in the ſtars;
" Take a breakfaſt with Merc'ry, & dine, if I pleaſe,
" With Jupiter, Saturn, or Mars.

" But ſhould I fatigued and wearifome prove,
" While from planet to planet I'm dodging,
" With Venus I'm welcome to tarry all night;
" Where, on earth, can you find ſuch a lodging?"

Thus chaunted ST. CROIX, as he mounted his Car,
And ſat him undaunted within it;
Majeſtic he roſe, like a g.ſt in the air,
And pierc'd through the clouds in a minute!

POWLER, PRINTER, SALISBURY.

But this one is really something extra-special. It is, in fact, of great rarity, if not unique—unknown even to the Royal Aeronautical Society, repository of the world-famous Hodgson-Cuthbert Collection of aeronautical ephemera. So we can take it that this is the first time it has been printed since 1786. In that year of grace it must have been little known, having been published in Salisbury; and even the assiduous Mr. Cuthbert, who began his aeronautical collection in 1820, failed to secure a copy.

But what really delights me is that it is a new-found contribution not merely to the literature of ballooning, but to that of space travel. The imagery of that last verse but one reminds me that a shade more romance in our present outlook spacewards might become us.

● "Sometimes I think that the only thing we have in common with the Americans is the language," a top British airline man told a colleague the other day," and even that is hardly common, is it?"

This is the mood in which at least some delegates from both sides will go to Barbados next week to take a fresh look at the 14-year-old UK/US civil aviation treaty—the so-called Bermuda Agreement. All sorts of conflicts have arisen over this thing in recent years; aircraft range and air traffic have developed to a degree that couldn't have been foreseen by the original drafters (among whom, incidentally, were Peter Masefield and Sir William Hildred).

I suppose there will be the usual horse-trading, so wearisome to those who yearn for less politics and more free trade in air transport. "OK, we gave BOAC San Francisco - Tokyo," You can imagine a US delegate saying, "Now you give Northwest Hong Kong." Or, from a UK delegate: "If we give Pan-Am New York - Jamaica, can BWIA have Jamaica - Chicago?" And so on.

* * *

Restrictions always lead to counter-restrictions. So why not let's try and see whether liberality leads to counter-liberality, if that's the right expression? Let's strike a gentle, exploratory blow for more freedom of the air at Barbados. It's time that our thinking advanced from the present protectionist attitude of "less for some" to a more progressive policy of "more for all." And what the British and the Americans do in air transport others tend to follow.

I hope, incidentally, that when the Barbados meeting is over the decisions made will not be kept secret. If this happens, and we are fobbed off with a statement about "a full and frank exchange of views," I shall chain myself to the railings in Berkeley Square or write a letter to *The Times*, or both.

● We've often been told that this is the age of the specialist, be he goofle-switch panel hinge-pin designer, crossword-puzzle square-shader, or historian specializing in the first half-hour of the Industrial Revolution. Well, it ain't necessarily so.

Take Hilliard W. Paige, for example. He belongs to General Electric's Missile and Space Vehicle Department and was recently named "Engineer of the Year" for the Philadelphia area. He has taken a leading part in the development of the GEC operational nosecone and of an RF underwater-sound system for locating mines and submarines; preliminary design of a submarine thermal reactor for nuclear propulsion; development and production of the J47 and J73 turbojets; perfecting techniques and equipment for determining the allowable heat-transfer rate of a nuclear reactor fuel element; development of a sonic aerial torpedo; design of a computer for calculating the orbit of a satellite and for computing specific points on the orbit where thrust may be applied to circularize the orbit; and—wait for it, men —*the design of an automatic pinspotter for use in bowling lanes.*

Nosecones, turbojets, nuclear reactors, torpedoes, satellite orbits and bowling alleys—what makes you think the rest of us lead narrow lives?

● If *Flight* asks two companies producing similar equipment to comment on their work, the chances are that one of them will sit down with us and talk. The other will send an old sales brochure. From this one can draw two distinct conclusions.

Either the informative company is putting on an act to impress you with its knowhow, while the other really knows its stuff but isn't letting on.

Or the first company really does know the answers and is confident enough to talk about them, while the other company just doesn't know the answers. If you can grasp this reasoning, take your pick of the interpretations. If you can't, forget it, because it's really my problem, not yours.

● I give Sud Aviation as many marks for their advertising as I do for their airliner. Their latest—a full page in *Les Ailes* — shows two crew-cut French youngsters poring over a magazine, one wearing an expression of alarm and dismay, the other of utter disgust. The crew-cuts bristle with indignation.

Inscription: *"Oh! ils ont copié Caravelle . . ."*

ROGER BACON

Scene: Eagle's offices at Blackbushe. The hole was made one dark night by an elderly Austin that took sudden leave of the A30, jumped a ditch, and finished up right inside the office of Eagle's aircraft sales manager Michael Cullen. P.S.—No one was hurt.

His Excellence E. O. Asasu-Adjaye, High Commissioner for Ghana, recently sampled the Handley Page Dart Herald at Woodley. With him is E. Manley Walker of H.P. A production aircraft is to tour West Africa and South America, leaving within four weeks

AIR COMMERCE

GREEN LIGHT FOR THE ROTODYNE

THE £4 million Government development contract for the Rotodyne, announced in *Flight* last week, was the direct result of Fairey's merger with Westland. It will be recalled that the original offer (by the MoS as it then was) of a £4 million development contract for the Rotodyne was wholly dependent upon BEA's contract to buy the aircraft. Lord Douglas said that this was a situation he "very much disliked." Since no firm contract has yet been signed by BEA it seems that the £4 million became, on Duncan Sandys' succession to the Ministry, more dependent upon an industrial regrouping. It can be no coincidence that the Minister announced his approval to the contract only six days after the announcement of Fairey's acquisition by Westland.

Thus ends the long-drawn-out and much discussed controversy about Government support for the Rotodyne. Fairey's chairman, presenting his annual report last November, said: "Within the political context of the Government's insistence of company's merging, it is difficult to decide . . . whether to proceed with a project as large and complicated as the Rotodyne . . . without a sufficiently large Government order."

The way now seems clear for BEA to finalize with the manufacturers their provisional contract for six Rotodynes, plus an option on a further 14. A military order, believed to be for about ten aircraft to be operated by the RAF, is likewise approved in principle; and New York Airways are in no doubt about their requirements for the Rotodyne. One matter still remains in the air: this is a question of a Government development contract for BEA, to defray operational development costs of the Rotodyne. There were reports last December that the Ministry had promised the corporation a sum of £1.4 million for this purpose. No mention of this was made by Mr Sandys in the House last week.

THAT LATIN-AMERICAN UNION

MOVES towards the formation of an "Air Latin America"—a consortium mainly of non-IATA carriers of five South American nations—has aroused deep interest amongst observers of the turbulent South American air-transport scene. If the birth-pangs of Air Union can be taken as a reliable guide, many months may pass before differences of economy, traffic and temperament can be sufficiently resolved to weld the participants into a homogeneous airline consortium. But the first steps have been taken and the reactions of other carriers to such a powerful *bloc* are already under review. An initial account of the first tentative steps towards an Air Latin America was given in *Flight* for February 5; it is supplemented here with an on-the-spot appreciation of the present situation.

The embattled South American continent, writes an observer, is at present more or less split up into two rival camps so far as the various national carriers are concerned. Five countries—Chile, Colombia, Ecuador, Panama and Peru—started it all last November when they met in Panama City to work out the basis for a sort of Latin-American Air Union. It is as yet too early to make any definite predictions about the eventual success, or lack of it, which this project will have; but there is no doubt that the other South American carriers—and probably the international carriers as well—are awaiting developments with deep interest not unmixed with apprehension.

This anxiety is not based on fear of what might be termed mechanical competition, as even if the national airlines of all the participating countries do get together they would do so on a basis of extremely heterodox (and in most cases obsolete) equipment; in fact, not one of the five has formulated a jet-equipment programme. The obvious implication is a legal one, as there is little doubt that the airlines have the support of their respective governments and, among them, the five cover the whole western seaboard of South America, including such important capitals as Santiago, Lima, Bogota, Quito and Panama. The adoption of progressively more restrictive policies by the governments concerned could considerably hamper activities by carriers from other countries.

The wording of the official communiqué on the Santiago meeting (*Flight*, February 5) mentioned that discussion had centred around the feasibility of grouping together a fleet which should be enabled to carry out a unified effort and a "common aeronautical policy." The implication here is obvious, particularly when viewed in the light of the growing wave of chauvinism which is regrettably spreading over Latin America—particularly in Brazil, which has gone out of its way to make things difficult for foreign carriers, particularly those offering very modern equipment. It has, too, been considered significant that the most important countries of South America from an aviation standpoint—Argentina, Brazil, and Venezuela—were not invited to the conference and neither were any subsequent approaches made to them by the Five.

At present the situation appears to be that the Five are to form a working group to be known as ALA (Aerovías Latino Americanas) to operate exclusively on regional and international routes—i.e., cabotage services will not be undertaken by ALA. At the moment, the lines seem to stack up as follows: LAN-Chile (premier equipment DC-6B and Martin 2-0-2); CEA (C-46); COPA (DC-3, C-46); FAUCETT (DC-3, -4); APSA (DC-3, C-46). The equipment threat is therefore negligible, but the legal overtones are not. It is as yet impossible to say whether the five countries are contemplating a joint purchase of more sophisticated aircraft; at the moment it seems that they will base their actual operating competition on very-low-cost services, and if they do this there is no doubt that they will be successful, as the standard of living in South America (while it varies widely from country to country) is in general of such a nature as to make the potential customer extraordinarily receptive to fare reductions, even at the expense of speed and comfort. As regards safety, the few small lines which at present operate low-cost services up and down South America have a really excellent record.

RENFREW AND ABBOTSINCH

IN the three months that have passed since the idea was first mooted of moving Glasgow's municipal airport from Renfrew to the naval airfield of Abbotsinch, no decisions have yet been taken. But it is not to be inferred that the suggestion is in abeyance; it may be two years before a final decision is reached and this will depend upon the growth of traffic, the size of aircraft then in use (or likely to be coming into use) on Scottish routes and technical considerations affecting the development and extension of the two airfields. Recent comments by those most actively concerned have been as follows:—

A Renfrew airport official: "It will probably take until 1962 at least for every aspect of the plan to be considered. Our runway here is only about 25 or 30yd shorter than that it Abbotsinch, but we will be unable to extend it because of surrounding built-up areas. Abbotsinch could probably be extended for quite some distance."

An Admiralty official: "We are unable to make any statement. . . . Any information will probably have to come from either the Government or the Admiralty in London, and that will take a very considerable time."

Sir Patrick Dollan, chairman of the Scottish Advisory Council for Civil Aviation: "Technical inquiries into such a move are being carried out and have been for some time. Everything depends upon whether the Admiralty, the Ministry of Aviation and the Government agree to an extension of air services for Glasgow and the West of Scotland is necessary."

The question is an important one, not only because Renfrew is Scotland's older operational airport, but because it vies with Manchester as the United Kingdom's second busiest. The most recently published MoA statistics, for November 1959, show that in this month the number of passengers handled at Renfrew exceeded those passing through Ringway by nearly 4,000. Transport-aircraft movements, on the other hand, were 35 per cent fewer—an indication of the nature of the air traffic carried by Scotland's busy air transport hub. More routes radiate from Glasgow than from any other airport in the British Isles—London included.

AIR COMMERCE . . .

The Air Bridge's New Ferry

A COMPETITION to name Aviation Traders' ATL-98 car ferry is being held by the Channel Air Bridge Division of Air Charter, who are offering as a prize a free return journey for a car and two passengers from Southend to Calais, Ostend or Rotterdam. The aircraft will be used both on these services and the "deeper penetration routes" into the Continent on which a decision is awaited. Here is a progress report.

GOOD progress is being made with Aviation Traders' ATL-98, the new car ferry for the Channel Air Bridge. It is hoped that it will fly in October and that one aircraft should enter service before the end of the year. Assembly of the new nose that transforms a used DC-4 into a new ATL-98 is about to begin on a wooden jig that has been constructed at Southend, and this will proceed side by side with resolution of the remaining detail design problems. Of these, a complete new control run along the upper surface of the fuselage is one of the major engineering tasks that have still to be completed.

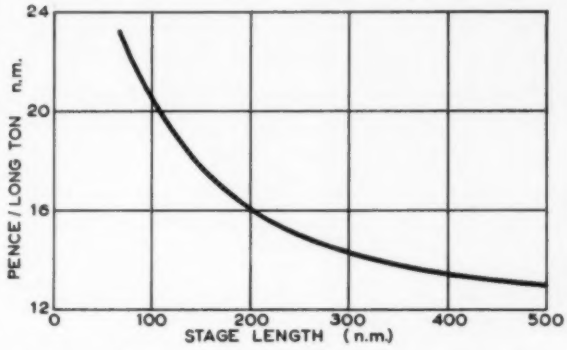
Aerodynamic design is now finalised. It has been considerably assisted by wind tunnel tests carried out by Douglas (who also supplied some thousands of engineering drawings) and by further tests in the ARA tunnel at Bedford.

Only one complete conversion is initially to be undertaken at Southend, although production of every item is to be in a first batch of four. A cautious production policy is being pursued to avoid over-extending the facilities available, but it is Aviation Traders' intention to make available at an early stage complete conversion kits for assembly by operators with suitable facilities.

Agreement has been reached with the ARB that the ATL-98 will be certificated in the existing unclassified performance group for aircraft on the British register. But detailed interest has been expressed in the design by 60 overseas operators and, should it be required, certification could be made to CAR 4B; there would be a "negligible" performance penalty.

Two-crew operation is envisaged, but accommodation for additional crew is provided, including a jump seat between and behind the pilots, navigator's station, and two aft-facing sleeperette seats for supernumeraries or for use during long-range charter or ferrying. Access from the freight hold to the flight deck is *via* a ladder. Two versions of the ATL-98 are available; a car ferry or mixed passenger/cargo freighter and a variant for long-range freighting. Although modelled on that of the DC-4, the cockpit—6ft 10in higher than in the DC-4 and giving a hold headroom of 6ft 8in—is modernized and has been re-engineered.

The sum effect of all the modifications is to provide an uninterrupted hold length of 81ft 2in and a capacity of over 4,500 cu ft, a contribution to which is made by moving the rear bulkhead 47in further aft than in the DC-4. A new removable bulkhead can be adjusted so that 20 passengers, four medium cars and one small car can be carried in the ferry role, or the division can be moved forward to provide a 32-seat compartment and a 60ft freight compartment; toilets will be provided for the passengers. The full freight length with the bulkhead removed is 81ft 2in—a useful capacity for an inexpensive (and inexpensive to operate) nose-loading freighter that should be available for charter operations next year. In past years Air Charter Bristol Freighters have been modified and used for occasional Air Ministry charters to Woomera; each required that the rear bulkhead should be removed and the journey time to Australia occupied eight days. Even as an adjunct to the car ferry business it seems a reasonable assumption that an ATL-98 could clearly carry out this task more efficiently—at least until RAF AW.660s become available.



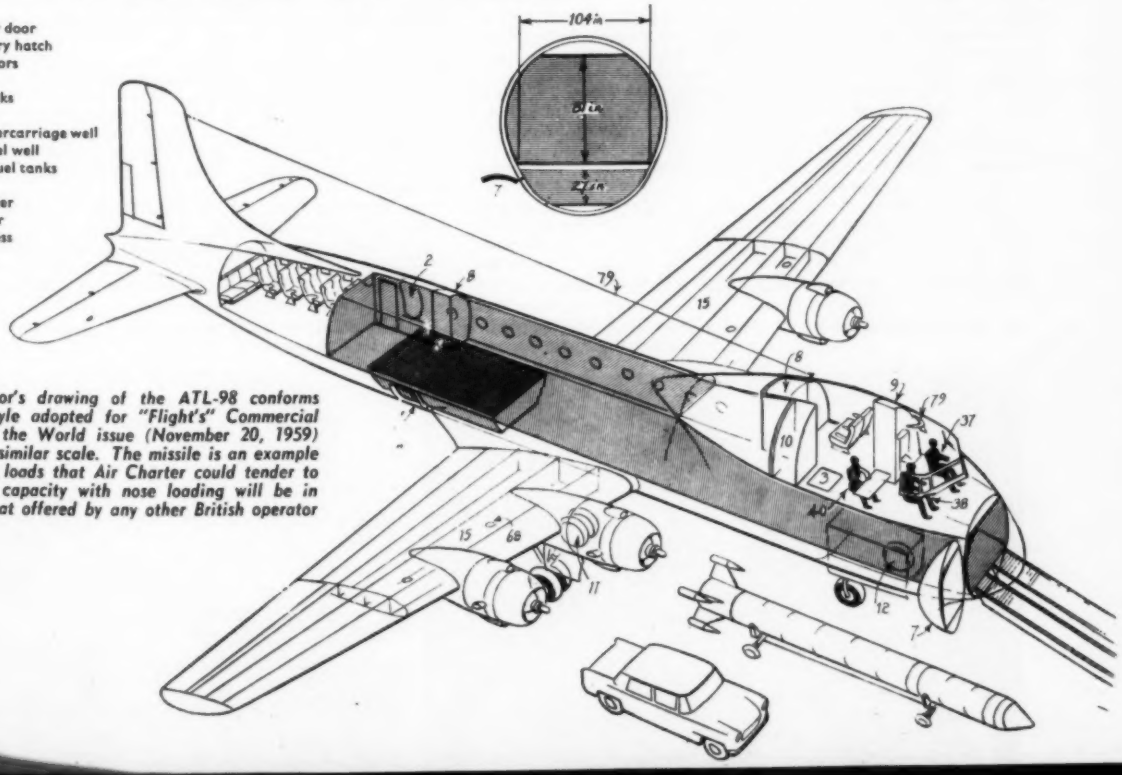
SBAC-method direct costs at 1,500hr utilization, two crew

Weights and loadings for the various versions are as follows:

Car Ferry—5 cars and 20 passengers: Weight empty, 40,372lb; operating weight empty, 41,824lb; payload, 15,900lb; zero fuel weight, 57,724lb (59,000lb max); fuel weight, 5,772lb; take-off weight, 63,496lb; range, 250 n.m. (IFR) with full SBAC allowances.

32 Passenger-Freighter: Weight empty, as above; operating weight empty, 42,525lb; payload, 16,475lb; zero fuel weight, 59,000lb; fuel weight, 14,200lb; take-off weight, 73,800lb; range, 1,475 n.m. with full SBAC allowances.

Long-range Freighter: Weight empty, as above; operating weight empty, 41,365lb; freight payload, 17,635lb; max zero fuel weight, 59,000lb; fuel weight, max take-off weight and range as 32 passenger-freighter.



This operator's drawing of the ATL-98 conforms with the style adopted for "Flight's" Commercial Aircraft of the World issue (November 20, 1959) and is to a similar scale. The missile is an example of the long loads that Air Charter could tender to carry. The capacity with nose loading will be in excess of that offered by any other British operator

AIR COMMERCE . . .

A 707 FOR PIA

AS announced on these pages last week, Pakistan International Airlines are to lease a Boeing 707 from PanAm with which to operate a service between Karachi and London. Teheran, Beirut and Rome will be served *en route*.

The arrangements which govern this lease are advantageous to PIA in a number of respects. In the first place, the 707 will be used by Pakistan on what is termed a trip-lease basis. In other words, both airlines will initially be using the same aircraft, and for a period while PIA crews and technical staff are trained, the 707 will operate over the London - Pakistan route flown by a PanAm crew and in PanAm colours, but with Pakistani cabin staff. Maintenance will be carried out by PanAm, who will charge PIA at a rate based on hours flown. This phase of the operation will cover one return service a week and will last until October.

In the second phase, when three 707 return services a week will be operated by PIA, pilots and flight engineers now receiving training in the US should have been checked out by the FAA and will be available to operate the aircraft. The trip-lease arrangement was agreed to by PanAm so that PIA could take early advantage of a jet service without curtailing existing services or overstraining its financial or manpower resources. The Pakistan airline also suggest that the arrangement will give them more time to become conversant with jet operations and to assess the type of aircraft that in two or three years' time they may want to consider for domestic operation. In the meantime, Super Constellations released from international services will provide additional capacity between the east and west wings of Pakistan.

There seems little question that PIA might place early orders for Boeing 707s. In the words of Air Commodore Mohd Nur Khan, the airline's managing director, "PIA is not in a position at the moment to purchase its own jets. The capital outlay is very large. Moreover, delivery time from most manufacturers is about eighteen months, which would leave us far behind." Nevertheless the lease arrangement does provide for the purchase of the aircraft from PanAm, and a price adjustment would be made to take account of past payments.

PIA are reported to be paying a sum in the region of $50,000 per round trip for the aircraft; they do not confirm this, but say that a figure has been calculated so that they will break even with an average load of 47 passengers (39 per cent load factor) plus "normal" mail and freight.

Relevant to the PanAm-Pakistan deal is a comment in the latest *Market Report* issued by Aircraft Exchange. It states that smaller scheduled airlines are finding the need for early delivery of turbine aircraft, whilst some of the larger airlines are making "minor adjustments" to their existing turbine fleets. The Exchange offers its assistance in the matching of this supply and demand.

SPRINGBOK'S UPS AND DOWNS

SOUTH AFRICAN AIRWAYS' Viscount fleet, introduced in December 1958, has brought a spectacular improvement to the airline's finances on internal and regional services. But its international flights are losing money. Figures given by D. C. H. du Plessis, South Africa's general manager of railways, harbours and airways, show that in the seven months from April to October last year, SAA's internal flights produced a profit of £138,000—£104,000 higher than the results for the same period in 1958. Revenues were up and expenditure was down, although there was a small loss on coach services.

The Springbok service to London during the same period, however, lost nearly £103,900, compared with a loss for the whole financial year 1958/59 of £59,000 and a profit for the previous year of £283,000. Mr du Plessis gave as the reason for this decline the economic recession, but he said that the general upward economic trend was expected to be reflected in increased traffic, and he reiterated SAA's intention of going it alone on economy fares if IATA has not agreed to them by the time that SAA's Boeing 707 fleet was in operation. Of the unprofitable domestic coach services, the general manager said that there was no question of withdrawing them because of initial losses; the new service needed time to build up patronage and he was hopeful of the prospects.

GOING THROUGH THE MOTIONS

IN the House of Commons on February 8 the Minister of Aviation, Duncan Sandys, said that he was "considering an application" from BEA for permission to operate a few scheduled services from London Airport at night with the Comet 4B. Before coming to a decision, he said, he had asked for noise trials to be held. Told by Anthony Royle (Con., Richmond, Surrey) that this statement would cause "widespread dismay" among thousands of residents living within ten miles of London Airport, Mr Sandys said, "I do not see why it should cause dismay to learn that I have decided to have noise tests before coming to a decision."

Obviously, the ordering of a noise test is one of the motions through which the Minister must go before he inevitably permits jet take-offs from London Airport at night. Once permission has been granted to BEA's Comet 4Bs permission for BOAC must follow, and then for the foreign jet operators who will be putting jets through London Airport this summer and who may wish to schedule outside waking hours.

It is understood that BEA have already been told that, based on the approach and climb-out techniques proposed for the Comet 4B, there will be no restriction on BEA Comet 4B flights from London Airport, provided there is compliance with the procedures agreed with the Minister. On the strength of this, BEA's advance summer schedules, released last week, include 16 Comet 4B movements a week between 2300hr and 0700hr.

Footnote: A Notam published by the Swedish Board for Civil Aviation on February 6 stated: "With immediate effect, take-offs with large turbojet aircraft, e.g., Caravelle and Comet, from Stockholm/Bromma Airport is prohibited between 2115hr and 0500hr GMT. Exceptionally, take-offs for test flights . . . may take place between 0400 and 0500hr," after which a report in writing must be made to the airport manager on the same day.

HERMES NEW LOOK

'PRIMROSE headlining and pale azure-blue roof panels . . . charcoal-grey kicking panels and soft grey walls . . . coral-red window surrounds and an old-gold carpet . . ." These rapturous phrases, which nevertheless fairly describe their subject, come from a brochure describing the cabins of the two Hermes 4s operated by Bahamas Airways (see picture). As explained in *Flight* of January 29, these two aircraft are now in service on the rich routes linking the Bahamas with Miami and other points in Florida. They will soon be competing on the Miami - Nassau route with Viscount 700s of Eagle Airways Bahamas, and the competition will be tough. But the veteran four-engined piston transports have been completely restyled to appeal to the American market and the renovation, the work of Skyways (to which Bahamas Airways, through Eric Rylands, is related) is worth putting on record.

As originally used by BOAC, the Hermes was a 56-seater. It was subsequently modified by Skyways to a 68-seater with an empty weight of 52,850lb. In its new configuration as a 78-seater it weighs only 52,603lb. The weight-saving has been accomplished mainly by removal of the pressurization system (its new Bahamas routes are short-haul), though air-conditioning is, of course, retained.

In order to meet ARB requirements for increased seating capacity, a large emergency escape exit has been introduced on the starboard rear side. A galley and a compact cocktail bar, both new, are styled in dove grey and red. Seat pitch is generally 36in (in some cases 39in) and the seats are covered in alternating colour

For services from the Bahamas, Skyways have extensively modified two Hermes 4s, equipping them with 76 seats, a new interior and galley and reducing the airframe empty weight. See "Hermes New Look"

blocks of blue and yellow to produce a most attractive effect. *Flight* understands that Mrs Eric Rylands played a leading part in the interior design. The cost of the conversion of two aircraft, complete with Check 4s, is said to be between £15,000 and £20,000.

WE READ IT AGAIN

A CAREFUL re-reading of the Bow Group's report* on Britain's airlines, reviewed in last week's issue, leads us to the considered conclusion that this is one of the best, and certainly the most comprehensive, studies of the subject to come our way. It received rather an indifferent press, most of the national dailies other than *The Times* and *The Financial Times* ignoring it completely, while reviewers in two serious weeklies didn't really tell anyone what the report was about, being too busy pretending they knew more about the subject anyway. But this brief return to the subject is not intended to be a review of the reviews: we should have picked up our pen again anyway to try to do justice to a work of rare honesty and originality.

The study has its imperfections. TWA did not kill 1,555 people in 1950-1958 (p. 68). And it is a widely held misconception that BEA and BOAC integrate their commercial services (p. 46)—there is virtually no co-operation, commercial or technical. There were two, not three Comet 1 pressure-cabin failures. Sir Gerard d'Erlanger deserves (for once) a pat on the back, but BOAC's DC-7C order was placed before his time (p. 59). The VC10 and D.H.121 may not be able to have swing tails (p. 81), but why not swing noses? British landing fees are very nearly the highest in the world, not just the highest in Europe (p. 70).

Otherwise, apart from some hasty proof-reading and the fact that events have overtaken some of the recommendations, this is a work of historical and technical scholarship; though we have never met the editor, one Tony Lucking, we imagine that few could match the all-round professionalism to which his 50,000 words testify. It is particularly refreshing to read recommendations based on an analytical appraisal of the issues. So much of the stuff we hear and read is based less on analysis than on preconceived political prejudices. It is a pity in a way that this book was sponsored by a group with allegiance to a political party. One inevitably reads it, or starts to read it, with the assumption that everything is angled to serve the cause of the Tory credo. But the political detachment of this study is platonic: apart from the bit about Sir Gerard, even the most rabid public-ownership fiend could hardly disagree that this study is politically sweetly reasonable.

It is odd that the daily papers did not get a story out of it. Do all those who advocate huge public subsidy for a new *Queen* know that two Boeing 707-420s costing £4m can shift 25 per cent more traffic across the North Atlantic in one year than a new *Queen* costing £25m? (p. 57). And in all the recent rail-strike controversy, it was only in this report that we saw reference to the railways' coming competition from the air, a trend which raises "serious doubts as to the wisdom of spending almost £2,000m on modernizing the railways" (p. 55). One of the best chapters in the report is devoted to suggestions (backed, as in the other chapters, by analysis) for the future of the UK's Cinderella internal air services.

In short, we recommend this book. Everyone interested in, or responsible for shaping, the destinies of British air transport should read it. It takes three or four hours to digest, but it is pleasantly readable, and once read it will constantly be referred to—especially its useful collection of graphs. J. M. R.

* *"Wings Over Westminster," published by the Bow Group, 22 St Giles High Street, London WC2. Price 7s 6d (8s post free).*

VLF "IN A FEW WEEKS"

ASKED in the Commons last week whether he could make a statement about the independents' proposed VLF (very low fare) services, the Minister of Aviation said that the necessary consultation with the other governments concerned was not yet completed. He hoped, however, to make a statement on the subject "in a few weeks' time." He thought it "most unlikely" that VLF could be introduced in April.

NEW BASE FOR SCOTTISH ATC

THE Scottish air traffic control centre, now located at Redbrae, Prestwick, is to be transferred by March 1963 to the RAF radar site at Gailes, on the main road between Prestwick and Irvine. There, new buildings, estimated to cost £300,000, will accommodate both the traffic control centre, the Scottish Air Communications Centre and the North Atlantic high-frequency radio telephone installations which are now at Birdlip, Gloucestershire. The VHF radio telephone units will continue to serve both the North Atlantic and the EuMed region.

The Ministry of Aviation has taken over from the Air Ministry the long-range radar equipment at Gailes, and will shortly bring it into operation. This will be the first use of ATC radar in Scotland, and one of the main functions of the Gailes unit will be to cover the Atlantic approaches—a sector on which most of the intercontinental traffic, eastbound and westbound, converges.

Airfield radar equipment, with a range of up to 40 miles, has also been installed at Renfrew Airport and is now in experimental use. Similar equipment will be employed at Prestwick Airport when the new control tower is opened next year.

Removal of the traffic-control centre from Redbrae was first made necessary by the decision to extend the airport. The existing buildings—a small mansion and a range of war-time huts—are to be demolished to make way for the new terminal. The site at Gailes extends to 180 acres. Initial development is being undertaken as part of the £5m development scheme for the whole of the UK air traffic control system.

Major advertising effort by BOAC in New York: a 75ft neon "spectacular" in Times Square with animated cartoons of scenes from countries to which BOAC operates

DOUGLAS CARAVELLE

THE question: "Will Douglas build the Caravelle?" posed in these columns on January 29 has been answered in the affirmative. In an historic statement issued in New York on February 10 by Donald W. Douglas and Georges Hereil it was announced that Douglas have rights to manufacture the Caravelle in the US, that they will co-operate with Sud in Caravelle development, and that they will represent the French firm in "all matters affecting the Caravelle" in what amounts to every part of the world except continental Europe and French-speaking areas.

Sponsorship of the Caravelle by Douglas, a firm that rarely "flies a kite" (an exception was the DC-9, now presumably shelved) suggests that a US airline order is now a certainty. The first will probably be UAL, who are expected to buy 20 plus an option on 20. No mention of powerplant was made in the statement; but it is known that GE's aft fan CJ805-23 is a strong contender as well as the Avon RA.29/6. General Electric will carry out a test installation on a Caravelle to be delivered to GE next July. Other by-pass contenders are Rolls-Royce, whose RB.141/3 is already selected for the 1963 Caravelle 7; Allison, who may licence-build this engine as the ARB.963; or Pratt and Whitney, whose fan JT3D series could be in the running.

The implications of the Douglas Caravelle's challenge to the D.H.121's export market are not easy to assess: one newspaper report last week suggested that plans are afoot for the D.H.121 to be jointly developed by D.H.-Hawker Siddeley with a US manufacturer.

Stop Press: As we go to press it is announced that United is likely to place its order for 20 Caravelles with Sud. They will be Avon-powered.

BREVITIES

It is now officially confirmed that the Minister of Aviation intends to sponsor the development of flight recorders for installation in both military and civil aircraft.

The Spanish report on the accident to a Transair DC-3 near Barcelona in August 1959 has been received by the Minister of Aviation, who is now studying it.

Eagle Airways have again applied to the ATAC to serve the London - Manchester route. This time both fixed-wing aircraft (Viking, Viscount and DC-6C) and helicopters are specified. A previous application was rejected by the ATAC in 1957.

The date fixed for BOAC to resume services through Egypt is April 10. Initially there will be four Comet 4 return services routed through Cairo on BOAC's Far Eastern route. During the past 3½ years BOAC's eastern-route services have been operated through Beirut.

As forecast in *Flight*, Austrian Airlines have placed a contract with Vickers for six Viscount 837s to replace the four 700s on charter from Fred Olsen. The first four aircraft will be delivered in March, the remaining two in June and July, and the first aircraft will go into service from April 1. A total of 416 Viscounts has now been ordered, including a recent executive sale.

WHAT COURSE FOR THE INDEPENDENTS?

(continued from page 232)

licensed applications could be sorted out and channelled. In effect that would mean only one application for the Air Transport Board to worry about.

"But bear in mind that much of the value of the service we now offer, the flexibility as well as the economy, is due to the fact that we are not hampered with a top-heavy and remote administration. We should not like to lose that quality."

* * * *

In their pleasing new Brompton Road offices the graph of Silver City Airways bookings showed the "achieved" curve consistently above the "target" for the year. And, quietly above all the bustle of the booking, **Eon Mekie**, chairman of the company, considers the wider aspects of British Aviation Services Ltd. His reply to my opening question about the outlook from his point of view was:—

"I can see no amelioration of the struggle which has always faced independents operating on marginal routes. It is going to be difficult to go forward as fast as we feel our initiative and skill merit unless we have an opportunity on the less marginal operations."

Yours is one of the larger groups. How do you visualize its role in the future?

"So long as our main effort is the Silver City operation then our immediate development should be in Europe, especially North-West Europe, where our shipping and other commercial connections should help us to develop freight and passenger traffic."

Do you see a future for all-freight operation?

"Not specifically. It is not easy to build up an all-freight operation if passengers are wholly excluded. With the assistance of passenger carrying licences we *could* later develop an all-cargo service. We believe in the freight potential, but not to the exclusion of passengers. The paramount consideration is safety, and if one is to have the necessary engineering and technical facilities throughout the route the overheads must be supported by the dual role. Interestingly enough, freight is a seasonal operation."

E. C. Mekie

Would you envisage concentrating on North-West Europe?

"Not exclusively. We have charter and contract flying elsewhere and that is growing."

But how would your European routes fit into the BEA pattern?

"BEA are able to maintain social services because they are 'carried' by more profitable routes. We cannot operate *only* on marginal routes. I hope that as a result of legislation, and without causing any material damage to BEA—maybe even the reverse in the long run—we will be given an opportunity to serve the more populated centres so that thereafter we can promote traffic in the less populated areas.

"But we really do not see this as a struggle between corporations and the Independents. Last century British shipping led the world, and if we are now given the opportunity to show initiative I am quite certain that we can increase the total volume of aviation work for this country."

What about the alleged benefits of rationalization?

"There is no gain in being gargantuan; the task is to ensure that we get true economies from the maximum utilization of equipment and staff. Certainly it seems to me that there are too many small concerns led by dedicated and honest people, but without the facilities that are required. Within the foreseeable future I should estimate that the number of independent operators or groups will be reduced to three or four."

To what extent will the cost of re-equipment contribute to this?

"I don't think the Independent will make much impact unless he has the equipment, and that implies more modern equipment than some operators can reasonably provide out of capital. It is not right that for new machines they should have to rely upon borrowed money at high interest-rates. Borrowed money ought not, in the future, to be such a large proportion of a company's working capital."

* * * *

To **Maurice Curtis**, managing director of Hunting-Clan Air Transport Ltd., who has grown up in the airline business, I opened with the same question about his general opinion on the outlook for the independent companies. He replied:—

"It is a two-pronged answer. The potential is there and we have not started scratching it as yet, but I am not too happy that the Minister's policy as we now know it will allow us to exploit the potential. The first essential as I see it is that all parts of the industry—corporations as well as Independents—must be enabled to get their business on to an economic basis. It must be made possible to become self-financing. No amount of policy changing will help the situation unless this necessity is met."

M. H. Curtis

And how do you see the role of your own organization in any future expansion?

"Assuming that there can be no big tear-up of present policy, then the future should mean a reasonable expansion of what we have already started. We have been particularly experienced in the low-cost field and we have put more money into freight than most people realize. We should be allowed to expand these operations, provided we can show that they are economic.

"The big expansion is going to come with the low-cost operation, and we want encouragement—including the development of cargo. Having said that, we must be enabled to pay our way and that may well mean marginal clashes with the corporations. To watch this sort of thing should be the responsibility of the licensing authority with, of course, the Minister in the background."

What do you need particularly from the Government to enable you to fulfil the role as you see it?

"We want the right conditions; fewer restrictions on types of aircraft; and our share of mail when we can give better services to the public. In my view long-haul freight from the UK is not economic, but it must be developed, and that means another category of service to go with it—the fill-up passenger, for example. In the United States mails go with these freight operations, and the operators are now getting some of the military traffic as well.

"Moreover, when we talk of the low-level fare bracket we do not necessarily mean that this should be reserved to us for all time. Nor that we should be restricted to such services. But the immediate necessity is to get things moving. When we have brought about the first big expansion, then in another five years or so a re-adjustment between Independents and corporations might mean that instead of a horizontal split as between the higher and lower fare traffic we might get a vertical split, with the corporations carrying some freight and low-fare passengers whilst we are allowed to go into the higher-fare business. It would be a mistake to get another over-rigid pattern.

"Then we need security. Again I emphasize that the public now know that they can get a low-cost operation and in one way or another it must be provided. It is much better for the Government to make it possible legally without encouraging shady evasions.

"Apart from the Colonial possibilities—and there they are screaming for low fares—there is the possibility of bilateral agreements between countries at each end of a route, say the UK and Canada."

What about rationalization?

"We have not had any experience of this yet, but the objective must be to build a stronger group with a pooling of skills and resources. The key factor is the reduction of costs."

Is re-equipment of the independent companies going to present any problem?

"We ought to be ready to consider the freer interchange of equipment on normal commercial terms between one unit of the industry and another. We want also an aircraft which is primarily a freighter if we are going to secure the maximum expansion of low-cost freight operations. Look at the orders placed for the Canadian CL-44. What have we to offer in this country?"

Cranwell today: a typical ceremonial scene at the RAF College, which celebrated its 40th anniversary on February 5 (a reminiscent article was published in "Flight" for that date). The buildings, designed by the late Sir James Grey West, were first occupied in September 1933

SERVICE AVIATION

Royal Air Forces and Naval Flying News

Visiting SE Asia

AT the end of last month the Chief of the Air Staff of the RAAF, Air Marshal Sir Frederick Scherger, left Australia by Hercules of the RAAF Transport Wing to inspect RAAF personnel in south-east Asia. He was spending several days at Butterworth, the big RAAF base in Northern Malaya where there are two fighter squadrons and a bomber squadron and nearly 1,000 Australian airmen are stationed. In Singapore the Air Marshal was to have talks with the Australian High Commissioner and the C-in-C FEAF, Air Chief Marshal the Earl of Bandon.

For Cyprus Services

TWENTY-THREE members of the Royal Air Force have received honours and awards in recognition of distinguished service in Cyprus, as follows:—

HONOURS

Order of the Bath

Companion: AVM C. T. Weir, CBE, DFC.

Order of the British Empire

Officer: Wg Cdr J. F. Oliver, RAF Regt.

Members: Fg Off A. E. Jones, RAF Regt; Plt Off A. Greenhalgh.

AWARDS

AFC: Flt Lt K. W. Woodcock.

Royal Red Cross (Second Class): Flt Off H. M. Cookson, Princess Mary's RAF Nursing Service.

BEM (Mil): Ch Tech T. V. Morgan.

Mentions in Despatches: Rev A. D. H. Northridge, BA; Sqn Ldr A. Smart, BEM; Sqn Ldr L. Agar-Wilson; Flt Lt R. Ellis, MB, ChB; Flt Lt A. Gavan; Flt Lt P. Morris, BEM, RAF Regt; Flt Lt D. Proctor, RAF Regt; Fg Off C. W. Cornish; Fg Off J. J. Ridge, BA, RAF Reserve of Officers; F/sgt J. Haddon, RAF Regt; Ch Tech W. H. Bradley; Sgt B. F. Naylor, RAF Regt; Sgt D. F. G. Baxter; Cpl R. D. Harding, RAF Regt; SAC E. D. Greig; SAC V. Hodgson.

Prime Instrument

ONE of the first things the AOC-in-C Transport Command, Air Marshal Sir Denis Barnett, said in his Brancker Memorial Lecture on February 1 on *RAF Transport Command* was something about what that command is. "In conversation I have heard it defined in many quasi-exact terms," said Sir Denis. "As an airline. Or as a charter company. Or sometimes as a fire brigade. Or, in certain contexts, as a weapon system which launches a khaki weapon. Or as a prime instrument in keeping the cold war cold. . . . It is, of course, not quite and not continuously any single one of these things, except perhaps the last, but it has something in common with all."

Speaking of the Command's equipment, Sir Denis paid tribute to the Handley Page Hastings and said it would endure beyond the initial stage of the introduction of the AW.660—"which is colloquially, but not quite correctly, referred to as its successor." He had a pat on the back for the Blackburn Beverley, which "has perforce been called upon to undertake duties for which it was not intended;" of the D.H. Comets he said of the Middle East operations in the summer of 1958 that there was "no doubt that our possession of the small Comet fleet saved the day;" of the Britannias, that they would redress the shortcomings of the Transport Command fleet in range, "and satisfy in part our need for speed and load;" and of the Command's aircrew commented: "I am today the proud inheritor of a crew complement which, in its professional standards of crew competence and of captaincy, is second to none."

Of future needs, Sir Denis said that expansion was needed in the numbers and types of short-range transports; in long-range work, "really high and progressively contemporary performance in at least an element of our strategic fleet;" and on "strategic poise and speed": "if one peers ahead no further than the already contemporary Comet 4 and the almost contemporary VC10 the current times of execution, which now are measured in days, become measurable in hours." It was essential to exploit, and not squander, "our acquired store of turbojet technique."

ATC Deputy Commandant

UNTIL recently attached to the Ministry of Aviation, Gp Capt A. G. Dudgeon has been made Deputy Commandant of the Air Training Corps with the acting rank of air commodore. Among his RAF posts before going to the Ministry of Aviation were the command of RAF Benson and (from 1954) of RAF Bruggen in Germany. He was awarded the DFC in 1941 and mentioned in despatches the same year. In 1955 he was made CBE.

IN BRIEF

Thirty-five RAF officers are shortly leaving for Norway to attend winter survival courses run by the RNAF.

* * *

A service of thanksgiving to mark the 40th anniversary of the RAF Benevolent Fund is being held at the RAF church, St Clement Danes, on April 2.

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A luncheon to mark the retirement of Sqn Ldr J. McIndoe, who since 1954 has commanded No 152 (City of Hull) Sqn of the ATC, was held at RAF Leconfield on January 31.

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AC P. Worthington was recently awarded the Queen's Commendation for Brave Conduct for assisting in the rescue of an officer in danger of drowning whilst bathing near Episcopi in Cyprus.

* * *

Wg Cdr W. Norrie, who recently retired from command of the Aberdeen and North-east Wing of the ATC, was presented with an inscribed silver salver by Sqn Ldr A. Dale, the CO of No 107 Sqn, at a luncheon in Aberdeen on January 31.

* * *

No 847 Naval Air Sqn, which was recently paid off, flew 1,687 operational sorties in Cyprus, entailing more than 4,000hr flying, from the time they started operations on April 12, 1956. Equipped with Gannets, the squadron formed part of the Cyprus Maritime Patrol, which has now been gradually reduced.

RETROSPECT: *From "Flight" of February 19, 1910*

Motor Union (Aviation Section). (Caxton House, S.W.): Major J. N. C. Kennedy gave a lecture on Tuesday evening, at the Royal Societies Club, on "Aviation from the Military Standpoint," in which he considered how airships could be used during hostilities both ashore and afloat. By means of lantern slides he illustrated how aerial craft might be used in future engagements. There was just a possibility, he pointed out, that aviation might effect a desirable result from a humanitarian standpoint. With two opposing forces manoeuvring in the field there could, in future, be no secrecy as to their disposition or strength—the commanders would know exactly to which side would fall the victory. In the circumstances, would the general who found himself at a disadvantage be justified in risking an action, or would the authorities at the War Office, who, of course, would also know the situation, allow the general to engage? When the conclusion was so apparent, would any useful object be attained by fighting the position? These considerations suggested that we were nearing the time when war would be no more.

The photograph referred to by C. C. Wakefield & Co. Signed by Maj J. C. Savage and Capt Cyril Turner, it bears the caption:—
"Photographed on June 1st, 1922. Patentee, Major J. C. Savage. Pilot, Captain Cyril Turner. Aeroplane 2 miles high. Length of word 'Castrol' 3 miles: depth half-mile. Smoke used 50 million cubic feet. Visible 4 minutes. Wakefield is the first firm in the world to use the sky as a hoarding."

Correspondence

The Editor of "Flight" is not necessarily in agreement with the views expressed by correspondents in these columns. Names and addresses of writers, not for publication in detail, must in all cases accompany letters.

Polymorph Patent

REFERENCE Roger Bacon's note (page 52, January 8) on the disclosure of the Wallis Polymorph principle: The first public account occurred by the issue of United States Patent No 2,915,261 in December 1959, presumably with permission from the Ministry of Aviation and the US State Department, as the United Kingdom Patent application corresponding to it is not recorded and must be presumed to have been filed under secrecy conditions. The UK Patent is not yet published, possibly for printing delay reasons.

Radlett, Herts — R. C. PETERSEN

Early Sky-writing

WITH reference to the article, on page 156 of your issue of January 29, entitled "Words on the Sky," we thought that you might be interested in, and might like to publish, the enclosed photograph [reproduced above—Ed.].

The details contained in the caption make interesting reading, particularly in comparison with similar information given in your article.

London NW1 — C. C. WAKEFIELD & CO LTD,
Kenneth Fossey, Group Public Relations Department

Early Days of the RAF

I READ with interest J. C. Corlett's reminiscences of Cranwell in your issue of February 5; I feel compelled, however, to draw attention to the reference to ". . . the new titles of rank which had been introduced with the amalgamation of the RFC and RNAS into the Royal Air Force on April 1, 1918."

I am afraid Mr Corlett's memory is at fault here; so far as the RFC officers were concerned, their titles of rank remained the same on the formation of the Royal Air Force. The titles at present in use in the RAF—flying officer, flight lieutenant, squadron leader, etc.—were not introduced until some time later [actually August 4, 1919.—Ed.]. I am quite certain of this as I myself was demobilized from the Royal Air Force in March 1919 and then held the rank of lieutenant. There was certainly no such rank as flying officer at that time.

On the other hand, on the formation of the RAF, sub-lieutenants RNAS became lieutenants RAF, lieutenants became captains and squadron commanders became majors. Most of the officers of my squadron had served in the RNAS until the formation of the RAF and at the time of the squadron's disbandment in March 1919 held Army-type ranks as above.

If my memory serves me aright, there was some discontent at this time amongst ex-technical RFC officers, since owing to the superior rates of pay, rank for rank, of Naval engineering officers serving with the RNAS when compared with those of RFC officers, engineer lieutenants in the RNAS became majors and engineer lieutenant-commanders were made lieutenant-colonels in order to avoid a reduction in pay on transfer to the new service.

I feel sure that the foregoing could be confirmed by reference to your columns of the appropriate dates.

It may also have been forgotten that the uniform introduced for the RAF on its formation was khaki in colour and blue was not introduced until a few months later—about July 1918, I think. The officers' khaki jacket was much the same in style as that now worn in blue. The cap was similar to a Naval officer's cap except for the khaki crown. Badges of rank for junior officers in the form of vertical bars were worn on each side of the cap badge, which was similar to the present badge. The cap had a glossy black peak.

I still possess my khaki RAF jacket and cap.

Farnham, Surrey — R. N. BELL

From the Soviet Archives

IN the middle of the 19th century in Russia was conceived the idea of rocket flight—flight with jet propulsion. One of the pioneers of rocket flight was the Russian engineer Theodor Romanovich Geshvend. He was born in 1841, educated in the Civil Engineers' Institute at St Petersburg and adopted civil engineering as a profession. He worked as an engineer-builder at Kiev and built many big houses. He became imbued with the burning enthusiasm for heavier-than-air flying—an enthusiasm that speedily took practical shape in the construction and building of a jet aircraft. He devoted his whole life to the study of jet flight at a time when in Russia people looked upon such a pursuit as little better than lunacy. In December 1866 he published in Kiev a brochure entitled *General Basis of the Project of Application of Jet Work of Steam in Railway Locomotives*. Four months later Geshvend published his second brochure, *General Basis of Construction of Aeronautical Steamer* (*Paroliot*). Geshvend suggested aerial navigation between Kiev and St Petersburg, on a biplane carrying 12 passengers, with a top speed of 260km/hr, flying by stages. Powerplant of the biplane is a jet engine, the fuel kerosine. In this brochure he cited data about "the indicator work of the goose" and the project of his jet engine of 350 goose power! In May 1887 Geshvend published his third brochure—about the jet engine.

He leased from the peasants of the farmstead of Rybnoie, near Kiev, the sandhills and built there a take-off estacade, a rail-track on not high pillars, for the running start of his steam jet aircraft (in Russian—paroliot). He devoted all his spare time and all his money to aviation. The very expensive experiments with this steam jet aircraft ruined the experimentator. He often said that his budget restrictions led to stoppage of the experiments. The family troubles on this ground brought Geshvend to a sad end. He went mad and died in 1890 in the Cyril Lunatic Asylum at Kiev, ironically, in the same asylum which was built by his design.

Tartu, Estonia — E. MEOS

[Our correspondent, who was kind enough to send his congratulations on our "fine magazine," is an aviation historian and former pilot. Since 1919 he has been turning up contemporary records of the pioneers of flying, and early designers of aircraft, in Russia and Estonia. The information in the letter above was gathered "in the archives at Kiev and Moscow."—Ed.]

CORRESPONDENCE IN BRIEF

Kenneth Poolman—author of *Faith, Hope and Charity* and other aviation books—is at work on a book about the RFC and particularly wishes to get in touch with former members of No 39 Sqn who served with it in 1916. His address is: "Linden," Vale Close, Frensham Vale, Farnham, Surrey.

FORTHCOMING EVENTS

Feb. 19. Institute of Navigation: Discussion on Space Navigation, introduced by Dr J. G. Porter.
Feb. 22. RAeS: Trenchard Memorial Lecture (at Halton Branch), "A Dip into the Future . . .," by Sir George Edwards.
Feb. 23. Institute of Transport (West Middlesex Group): "Aircraft of the Future," by R. C. Morgan.
Feb. 23. RAeS: "Theory and Practice in Structural Problems," by A. J. Troughton.
Feb. 23. British Interplanetary Society: "Some Problems Encountered in the Design of Large Rocket Test Beds," by R. H. B. Forster and L. Breen.
Feb. 23. Guild of Air Pilots and Air Navigators: Banquet.
Feb. 23. RAeS: "Relationship between Theory and Practice in Structural Problems," by A. J. Troughton.
Feb. 24. RAeS Man-powered Aircraft Group: Lecture on "Natural Flight," by Peter Scott, postponed until further notice.
Feb. 24. Royal Society of Arts: "The Exploration of Outer Space," by Prof A. C. B. Lovell.

RAeS Branch Fixtures (to Feb. 26): Feb. 19, *Birmingham and Wolverhampton*, "The Rolls-Royce Tyne," by D. Maclean. Feb. 22, *Cambridge*, Film Show. Feb. 24, *Christchurch*, "Man-powered Aircraft," by B. S. Shenstone; *Hatfield*, "The SR-N1 Hovercraft," by R. Stanton-Jones; *Reading*, "Car Ferry Operation and History of Silver City Airways," by M. D. Day. Feb. 25, *Belfast*, "Blind Landing," by W. J. Charnley; *Bristol* (Junior Committee Lecture), "The SR-N1 Hovercraft," by R. Stanton-Jones; *Isle of Wight*, "The Economic Basis for Design of a Freight Aircraft," by A. H. Stratford.